Water, environment and agriculture: challenges for sustainable development

Proceedings

N. Lamaddalena, M. Todorovic, L.S. Pereira (Eds.)
1st CIGR Inter-Regional Conference on Land and Water Challenges

Water, environment and agriculture: challenges for sustainable development

Proceedings

N. Lamaddalena, M. Todorovic, L.S. Pereira (Eds.)

10-14 September 2013, Bari - Italy
Contents

Preface ........................................................................................................................................13

Introduction ..............................................................................................................................15

Conference Scientific Committee ..........................................................................................17

Conference Honorary Committee ..........................................................................................18

Conference Organizing Committee .......................................................................................18

Key Notes

• Crop Evapotranspiration: the 15 years of FAO 56 .................................................................21

• Evapotranspiration Estimation with FAO56 Methodology: The Next Fifteen Years ..................22

• Managing water in agriculture under increasing scarcity: Need for a paradigm change ................24

• Assessing the productivity and resource-use-efficiency of underutilised crops: towards a integrative system ..................................................................................................................25

• Landscape irrigation requirements and scheduling ...............................................................27

• Adaptation strategies for agricultural water management under climate change ....................28

• Achieving ethical responsibilities in water management: a challenge .................................29

Session 1

Water use performance and water productivity

• Yield and Water Use Efficiency of Durum Wheat Cultivars under Different Sowing Dates and Water Regimes ........................................................................................................33
• Assessing yield and water productivity of peas 
  (*Pisum sativum* L. cv. Azarro) in a Mediterranean environment .................. 34

• Modelling evapotranspiration of seed propagated Globe Artichoke in a 
  Mediterranean environment .............................................................. 36

• Water use and crop coefficients of celery and fennel in Mediterranean 
  environments .................................................................................... 38

• Dual crop coefficient modeling applied to soybean: basal crop 
  coefficients and soil evaporation component ....................................... 40

• Accurate large-scale irrigation performance assessment 
  with a poor dataset ........................................................................... 41

• Response of water status indicators to water stress in olive tree .......... 43

• “WP_optimizer” to improve water productivity in irrigated 
  agriculture in Egypt ........................................................................... 44

• Effect of different fertilization and irrigation methods on nitrogen 
  uptake, water and radiation use efficiency of okra grown in the 
  Keta sand spit, Ghana .......................................................................... 45

• Effect of Two Different Irrigation Techniques and The Application
  Of The Partial Root Zone Drying Technique on Potato Crop ............... 47

• The influence of feeding strategies on water productivity in dairy farming ...... 49

• Tangor “Ortanique” Response to Soil Water Regime ............................ 51

Session 2
Conservation agriculture and water saving

• WADIS-MAR - Water harvesting and Agricultural techniques in Dry 
  lands: an Integrated and Sustainable model in Maghreb Regions .......... 55

• Co-design of innovations for sustainable small-holder irrigation:
  The EAU4Food project case study in South Africa ............................... 57

• Effects based on Soil and Water Storage of Water harvesting practices ....... 59
• The Experimental Study of Influence of Biochar on Different Texture Soils Hydraulic Characteristic Parameters and Moisture Holding properties .......................................................... 60

• Evaluation of Linear Anionic Polyacrylamide (LA-PAM) Application to Irrigation Canals for Seepage Reduction .......................................................... 61

• Role of plastic mulch on soil moisture availability for kiwifruit vines ................................................................................................................................. 62

• Improvement of plant growing techniques in drying up and water scarcity conditions ........................................................................................................... 63

• Irrigation with magnetic water, a novel tool for improving crop productivity and water use efficiency ................................................................. 64

• Evaluation of effects of soil moisture content and wind condition on wind erosion in bare soil field .................................................................................. 65

• Pest control and mitigation of the heat stress with kaolin may also lead to save water in Mediterranean environments ....................................................... 66

• Smallholders Minimum Tillage Planter Adoption in Bangladesh: A successful case of private sector involvement for technology commercialization .......................................................... 68

Session 3
Sustainability of groundwater exploitation for agriculture

• GeSAP: a management tool to evaluate the acceptability of irrigation constraint measures for groundwater protection ................................. 73

• Comparative study for Estimating Ground-Water Recharge from Hydrograph Analysis and Groundwater Fluctuations in Semiarid to dry subhumid Region - Case Study of Al-Khazir Gomal Basin North of Iraq......... 75

• The sustainability of groundwater exploitation for agriculture in the case of a wide coastal karstic aquifer (Salento, Southern Italy) ............ 76

• Investigation of the relationship between groundwater level fluctuation and vegetation cover by using NDVI for Shaqlawa basin of Kurdistan region, Northern Iraq ................................................................. 77
• Irrigation Delivery Performance Versus Environmental Externalities: A Risk Assessment and Management Perspective ........................................ 78

• Groundwater Recharge in Titas Upazila in Bangladesh ........................................ 79

• The KNOW project (implementing the Knowledge of NitrOgen in groundWater) implementation in a NVZ Sardinian area ....................... 80

• Groundwater dynamics at irrigated field scale: Case study from Lower-Mondego Irrigation District, Portugal ................................. 82

• Possibility of geothermal exploitation in south Algeria for agriculture .............. 84

Session 4
Decision support systems and modelling tools

• Hydro-Tech, an integrated decision support system for sustainable irrigation management: (I) main algorithms and field testing ....................... 87

• Hydro-Tech, an integrated decision support system for sustainable irrigation management: (II) software and hardware architecture .... 89

• Tools to support water management in agriculture under policy and climate change. The Trebbia irrigation district experience .............. 91

• Modelling approach for agriculture water management ................................... 93

• The Application of Simulation Models for Assessment and Impact Analysis of Drought and Water Requirements at Different Scales .......... 95

• Aqua Crop as a decision support tool to assess the effect of field management on crop water productivity ................................................. 97

• Comparing AquaCrop and CropSyst models in simulating barley growth under different water and Nitrogen regimes. Does calibration year influence the performance of crop growth models? .... 99

• Calibration of CropSyst Model for Wheat Grown under Three Soil Conditions in Egypt ................................................................. 100

• Design guidelines for surface irrigation modernization in Hetao Irrigation District. An application of the DSS Web Sad Reg ................. 101
**Session 5**

**Innovative data-acquisition and information and communication technologies**

- Design of sprinkler irrigation subunit of minimum cost with proper operation. Application at corn crop in Spain .................................................. 103
- Rainfed maize in Inner Mongolia: evapotranspiration partitioning and groundwater contribution ................................................................. 104
- Modelling maize deficit irrigation in Galicia (NW Spain) ........................................................... 105
- Calibration and validation of the Hydrus - 1D model to simulate soil water balance of maize under full and deficit irrigation ................................. 106
- Solid-set sprinkler irrigation controllers driven by simulation models: opportunities and bottlenecks ................................................................. 107

- Satellite-based Irrigation Advisory Services: a common tool for different experiences from Europe to Australia .................................................. 111
- Crop coefficients derived from METRIC and SIM Dual Kc models for discontinuous woody crops. A remote sensing application to a super intensive olive grove ................................................................. 112
- Crop evapotranspiration through the use of satellite images ......................................................................................................................... 114
- Assessment of Soil Water Content based on Remote Sensing Techniques. Case study of kiwi Orchard in Portugal ............................................. 115
- Use of pyranometers for continuous estimation of ground cover fraction in orchards ...................................................................................... 116
- An approach for delineating homogeneous within-field zones using proximal sensing and multivariate geostatistics .................................. 118
- Evaluation of physiological and biometric parameters of potato (*Solanum tuberosum L.*) under different water regimes by proximate sensing .................................................................................. 120
- Reference evapotranspiration estimation for the Mediterranean region using reanalysis datasets ..................................................................... 121
• Estimating reference evapotranspiration using weather forecast data in Southern Brazil .......................................................................................................................... 122

• Developing an intelligent overhead irrigation system for high quality horticultural field crops .......................................................................................................................... 124

• Determination of leaf area index in vineyard using Unmanned Aerial Vehicles (UAV) ................................................................................................................ 125

• Automatic analysis of multiple Beerkan infiltration experiments for soil Hydraulic Characterization ....................................................................................... 127

• Stem water monitoring of mesquite (Prosopis juliflora) using dielectric soil moisture probes in Sudan ......................................................................................... 128

• Using remotely sensed data to induce snow cover dynamics and water productivity for sustainable water management in Ibrahim River Basin, Lebanon .............................................................. 130

Session 6
Irrigation technologies and management practices for environmental upgrading

• Effect of the start-stop cycle of the drive towers of a pivot on the water distribution pattern .................................................................................................................. 133

• Evaluating and Modeling solid-set sprinklers irrigation of the field borders ...... 134

• Performances of subsurface drip irrigation compared to a raingun irrigation system for maize under water-restrictive conditions in a Mediterranean climate ........................................................................ 135

• Effects of drip, sprinkler and basin irrigation on micro-climate and fungal infection in winter wheat in the North China Plain ................................................................................ 137

• Simulation of water flow and heat transport in a drip-irrigated onion under plastic mulch .................................................................................................................. 138

• Modeling and Simulating Flow Transient in Pipeline Systems: Pump Combined with Closed Surge Tank ......................................................................................... 139
• Performance of the microsplinkers with microtube nozzle as a Discharge controller ................................................................. 140

• Small hydro power implementation in an existing irrigation network of a Water User Association (Southern Italy) ......................................................... 142

• Linking Crop Water Stress Index (CWSI) and water stress coefficient (Ks) to support irrigation scheduling of wheat grown in Mediterranean environments .................................................................................................................. 144

• Crop water stress index for assessing irrigation scheduling of drip irrigated summer squash (Cucurbita pepo L.) .................................................... 145

• New Apulia Nitrates Action Plan: identification of suitable policies aimed to reduce water pollution and improve environmental sustainability on regional scale ..................................................................................................................... 146

• Managing modern irrigation technologies for the sustainable use of water in Mediterranean agriculture .............................................................................................................. 147

Session 7
Use of treated and low quality water in agriculture

• Water4Crops: A twin project for Integrating biotreated wastewater reuse and agro-food wastewater valorization with enhanced water use efficiency to support the Green Economy in Europe and India .................. 151

• Properties of the filtrate from processing of the pig manure by filtration method .................................................................................................................. 153

• Degradation of antibiotics in livestock wastewaters for environmental protection: laboratorial experimentation using ligninolytic fungi ......................... 154

• Macroscopic root water uptake under salt stress and non-uniform salt distribution: I. Column-scale experiments ..................................................... 156

• Parameterizing macroscopic root water uptake under salt stress and non-uniform salt distribution: II. Field-scale experiments .............................. 157

• Saline water use: effects on soil salinity and alfalfa production under date palms in the Algerian Oasis ............................................................................. 159
• SWIM Sustain Water MED Network of Demonstration Activities for Sustainable Integrated Wastewater Treatment and Reuse in the Mediterranean (The Jordanian pilot project) ................................................................. 160

• On the effectiveness of reusing treated wastewaters by infiltration ponds in coastal farmlands. Preliminary investigation on insights from the Korba site, Tunisia ................................................................. 162

• Water multi-purpose reuse case study: the Yarqon River Rehabilitation Project .......................................................................................................................... 163

• Agent-based study of stormwater re-use system operational capabilities during drought .......................................................................................... 165

• Hydrocarbons removal from water bodies using biogenic adsorbents ............... 166

Session 8
Climate change: adaptation and mitigation

• Assessing irrigated crops’ adaptability under future climate: the interplay of water management and cultivars’ responses .............................................. 169

• Improving wheat agricultural practices to cope with climate change effects in Jordan ...................................................................................... 171

• Climate change and Mediterranean agriculture: Impacts on wheat and tomato crop water and irrigation requirements ...................... 172

• Climate change and Mediterranean agriculture: Impacts on wheat and tomato yields and water productivity ......................... 173

• Assessing the adaptive capacity of durum wheat cultivars to future climate .... 174

• Optimising irrigation practices of durum wheat and spring barley to cope with climate change effects in Jordan ........................................................................ 176

• Adapting to climate change: testing possible measures to stabilize wheat and barley yields in a Mediterranean environment ....................... 177

• Prediction of climate change impacts on cotton yields in Greece under eight climatic models using the AquaCrop crop simulation model ....... 178

................................................................. 8
• Impacts of climate change on olives crop evapotranspiration and irrigation water requirements in the Mediterranean region ............................ 179

• Adaptation to climate change of irrigation management of Peach tree cultivars................................................................. 180

• Farm adaptation strategies to cope with climate change in arid and semi-arid Mediterranean areas ........................................ 182

• The dynamic change of water based on Three-dimensional model in climate change conditions for Hulun Lake in Inner Mongolia, China .... 183

• Modeling Climate Change Impact on the Water Balance of a Coastal Watershed in Lebanon .................................................. 184

• Climate Change Impact on Snow Dynamics of the Lebanese Mountain Chains ........................................................................ 186

Session 9
Drought/Flood risk management

• Using drought indicators to support drought risk management in irrigated agriculture................................................................. 189

• Streamflow Drought Index modelling through Standardized Precipitation Index assisted by service-oriented paradigm .................. 190

• Drought and climate variability impacts on Bulgarian agriculture: the case of rainfed maize .................................................................. 191

• Assessing drought cycles using a Fourier analysis ................................................. 193

• Analysis of Drought using standardized precipitation Index ......................... 194

• Studies on runoff and erosion rates in Eastern Romania ............................... 195
Session 10
Socio-economic aspects of land and water management

• Hydro-economic modelling to assess climate changes impact on agriculture water management in a semi-arid region ................................................. 199

• Economic Impacts of Salinity on Livelihoods: The case of Al-Musayyeb in Iraq ................................................................. 200

• The role of traditional irrigation canals in a long term environmental perspective. A case study in southern France: The Durance basin ........................................... 202

• The Criticality of Integrating Local Agro-Economic Institutions into Paradigms for LDC Poverty Reduction in the Anthropocene ....................... 203

Session 11
Policies, governance and institutional development

• The EU-funded Sustainable Water Integrated Management Programme and its Support Mechanism: taking stock of the project ........................................ 207

• Connecting science with policy and innovation in order to improve water management in Europe .................................................................................. 209

• MEDSPRING: an example of open dialogue between research, civil society and policy makers .............................................................. 211

• Rural Water Access and Management Approaches in Southern Africa: Lessons from Namibia and South Africa ........................................................ 212

• Evolution of irrigation quality after the assistance for farmers: The experience of the advisory service for irrigators - SAI in “Baixo Acaraü” irrigation district ........................................................................... 214

• Irrigation advisory service in “Baixo Acaraü” irrigable area ........................................... 216
Session 12
Water-food-energy nexus, eco-efficiency and ecological footprint

• Moving water use efficiency up the food chain: addressing water footprints of food consumption and food wastage in the Mediterranean .......... 221

• Agri-irrigation systems under innovation: Prospects and difficulties of eco-efficiency improvements ........................................ 223

• Eco-efficiency of a large irrigation scheme in Southern Italy: system mapping and evaluation of different management options .............................. 224

• Sustainable “Nexus” in the Palù: Cultural Approach, Water Planning and Landscape Systems ............................................................... 225

• Expo 2015 Milan and Feeding Knowledge programme: the nexus between land, water, climate change, biodiversity, energy and food security in the Mediterranean ............................................................ 226

Supplement to Session 1
Water use performance and water productivity

• Distributed simulation of agro-hydrological processes and assessment of water productivity in irrigated areas of the middle Heihe River basin ............................................ 231

• Alternate skip irrigation: a new strategy to ensure productive sugarcane crop with less water use ............................................................................ 232

Supplement to Session 3
Sustainability of groundwater exploitation for agriculture

• Potential Risk of Groundwater Pollution by Nitrates in Northwestern Libya .................. 235

Supplement to Session 4
Decision Support Systems and modeling tools

• Adaptation of water planning to climatic and hydrogeological changes ...................... 239

Supplement to Session 6
Irrigation technologies and management practices for environmental upgrading
• Calibration of ML2-ThetaProbe to Accurately Monitor Plant Root Zone Water Content in Perlite and Cocopeat .................................................................243

Supplement and Errata Corrigenda to Session 7
Use of treated and low quality water in agriculture

• Comparison of methods for determining soil C-CO2 flux and analysis of the factors that affecting the flux, in growth of sugarcane irrigated with treated sewage by SDI..................................................................................247
• Chemical attributes in the soil profile after six years of cultivation with irrigated and fertigated coffee at two planting spaces .......................248

Supplement to Session 8
Climate change: adaptation and mitigation

• Introduction and assessment of quinoa in Pakistan as a potential climate resilient grain option for future food security .......................................................253

Supplement to Session 11
Policies, governance and institutional development

• Performance Evaluation of Transferred Irrigation Schemes of Gediz Basin, Turkey .....257
• Women in climate change adaptation and mitigation ..................................................258
• The System of Knowledge Transfer and Risk Management in Irrigated Agriculture.....259
• Managing scare water resources under competing demands: Zayandeh-Rud basin, Iran .....................................................................................260

Supplement to Session 12
Water-food-energy nexus, eco-efficiency and ecological footprint

• Planning food waste ..................................................................................................263
• Agricultural and industrial applications of geothermal energy.............................264
• Possibility of agricultural geothermal utilization in south Algeria..........................265
PREFACE

In the mid of 2012, the international Commission of Agricultural and Biosystems Engineering (CIGR) and the International Centre for Advanced Mediterranean Agronomic Studies – Mediterranean Agronomic Institute of Bari (CIHEAM-IAMB), Italy, agreed about the organization of the 1st Inter-Regional Conference on Land and Water Challenges in Bari, Italy. The increasing globalization and the development of science and technological innovations worldwide indicated this event from its beginning as truly international, and there was a need to invite the scientist from all over the world.

Since the 80’ of last Century, the advances in agricultural research lead to substantial increases in food production but the question of food security is again high-up on the international agenda. A number of factors are putting pressure on food security: population growth, insufficient agricultural infrastructure, land degradation, heavy disease burden, low fertility soils and highly variable climate. The problem is enhanced by climate change and its effects on water regimes and availability are not in favour of agricultural productivity and production stability. Large arid and semi-arid areas in the world have high productivity potential but water and salinity heavily limit production. In addition, these areas are often ecologically sensitive, prone to environmental degradation and in need of narrowing social inequities.

Irrigation will therefore gain importance, but the availability and quality of water resources and the potential use of soil resources are under increasing pressure by the non-agricultural sectors. The link between food security, land use and water resources is inevitable and new strategies are required in order to address water use, performance and productivity of agricultural systems.

The 1st Inter-Regional Conference on Land and Water Challenges, held in Bari (Italy), 10-14 September 2013, links water, environment and agriculture with the objective to discuss the latest achievements in the field of sustainable use of land and water at different scales and to promote a better development of agriculture in the future. Initially, more than 250 abstracts were submitted to the Scientific Committee. The proceedings of the Conference contains more than 110 contributions from all over the world including Africa, North and South America, Asia and Europe.

Given the importance of problems to be addressed, on behalf of the CIHEAM and MAI-Bari, I would like to thank the organisers of this conference, the experts, authors, keynote speakers and all other participants for their valuable contribution promoting a sustainable development of agriculture.

Cosimo Lacirignola

Director of CIHEAM,
Mediterranean Agronomic Institute of Bari
INTRODUCTION

At the beginning of 21st Century, the international society has declared the Millennium Development Goals (MDGs) aiming to eradicate extreme poverty and hunger, ensure environmental sustainability in the use of water and land, and sponsor global partnership for development. This year of 2013 is declared the International Year for Water Cooperation with the objective of raising awareness on both the potential for increased cooperation and the challenges facing water management in light of the increase in the demand for water access, allocation and services.

In the past decades, land and water management in the agricultural sector has become progressively more complex and dynamic, in which the hydraulic systems and agronomic practices need to be considered together with organizational, institutional, social and cultural issues to better integrate the related activities of operation, maintenance and management. Moreover, the continuous technological progress leads to notable changes in irrigation methods and equipment, which call for innovative management of irrigation water. In addition, irrigation mechanization and automation induce farmers to adopt new behavior, as well as changes in the socio-economic conditions of farmers. However, the access of small farmers to technological and managerial innovation constitutes presently a new challenge with major socio-economic dimensions.

Water, agriculture and environment are intrinsically linked throughout the scales: either considering the water pathway in the hydrological balance or through the components of soil-water and energy balance and the simple relations explaining sustainable water use, water and land productivity, and energy and nitrogen efficiency. Actually, agriculture consumes about 70% of the world’s water annual withdrawal and, due to limited availability of water, land and other resources, the challenge of our time is to promote the sustainable use of the resources and to produce more with less while respecting the environment, the rural landscapes and the human and cultural values of the diverse farmer societies.

In the years to come, the link between water and agriculture is going to be more tight, functional and complex due to multiple factors such as the changes in population growth, the trends for increasing the urbanized population, the changes in behavior of rural societies, temperature and water availability changes associated with climate change, and the progressive loss of agricultural land for use in favour of urban related uses. By the mid of this Century, the world population will reach at 9 billion and agriculture will need to produce almost one-third more food than today, thus facing the enormous challenge of increasing productivity with the unchanged or even reduced water and land availability and under a more variable and adverse climate, always bearing in mind the alleviation of poverty and hunger.

Certainly, many other changes will occur meanwhile including the political and financial arrangements, technological and socio-economic development, cultural setup, consumption patterns, and living and nutritional habits. These changing conditions will give raise to numerous scenarios describing the water-land-environment-agriculture interlinks within the
systems at local and global scale. It will result new socio-economic implications as well as technological and managerial constraints related to the availability and quality of water and land resources, the natural ecosystems and agricultural production. Likely, these uncountable scenarios of change will vary considerable over time and differ substantially in terms of magnitude and spatial location indicating the vulnerability of the natural and man-made ecosystems and causing concatenated effects in the distribution of resources among different economic sectors and different groups of the society.

The 1st Inter-regional Conference on Land and Water Challenges aims to discuss some of above issues and to propose solutions for many challenges that agriculture is going to face in the future. Accordingly, the conference is articulated into several sessions, including water use performance, water productivity and economics of water use, conservation agriculture and water saving, sustainability of groundwater exploitation for agriculture, decision support systems and modelling tools, innovative data-acquisition and information and communication technologies, irrigation technologies and management practices for environmental upgrading, use of treated and low quality water in agriculture, climate change: adaptation and mitigation, drought risk management, policies, governance and institutional development, and eco-efficiency. All these themes have attracted a variable number of people and, therefore, will be differently followed by the participants. However, it has been our intention to provide for a forum where participants with different backgrounds, scientific and technological objectives, or research approaches and priorities may discuss openly and contributed to the advance of knowledge and to build new and fruitful cooperation.

Nicola Lamaddalena
Mladen Todorović
Luis S. Pereira
CONFERENCE SCIENTIFIC COMMITTEE:

- Allen Richard G., University of Idaho, Twin Falls, USA
- Azam Ali Sayed, Crop for the Future Research Centre, Malaysia
- Carlesso Reimar, Federal University of Santa Maria, Brazil
- Carsjens Gerrit, Wageningen University, The Netherlands, Secretary of CIGR Section I
- Coppola Antonio, University of Basilicata, Italy
- Dubey S. K., Central Soil and Water Conservation Research & Training Inst., Agra, India
- Dukhovny Viktor, SIC ICWC, Tashkent, Uzbekistan
- Ferro Vito, University of Palermo, Italy
- Fratino Umberto, Polytechnics of Bari, Italy
- Gao Zhanyi, IWHR, Beijing, China, and President of ICID
- Garcia Mario, University of the Republic, Montevideo, Uruguay
- Hoogenboom Gerrit, Washington State University, USA
- Huang Guanhua, China Agricultural University, Beijing, China, Chairman of CIGR Section I
- Jovanovic Nebo, National Resources and the Environment (NRE) CSIR, South Africa
- Lacirignola Cosimo, Director, CIHEAM-Mediterranean Agronomic Institute of Bari, Italy
- Lamaddalena Nicola, CIHEAM-Mediterranean Agronomic Institute of Bari, Italy
- Oweis Theib, ICARDA
- Palacios Enrique, Colegio de Postgraduados, Montecillo, Estado de México, México
- Pereira Luis S., CEER, Institute of Agronomy, Technical University of Lisbon, Portugal
- Playan Enrique, CSIC, Aula Dei, Zaragoza, Spain
- Popova Zornitsa, N. Poushkarov Institute of Soil Science, Sofia, Bulgaria
- Rossi Giuseppe, University of Catania, Italy
- Scoullos Michael, Chairman, Global Water Partnership Mediterranean (GWP-Med), Greece
- Shatanawi Muhammad, University of Amman, Jordan
- Steduto Pasquale, FAO, Rome, Italy
- Tarjuelo José M., University of Castilla-La Mancha, Albacete, Spain
- Todorovic Mladen, CIHEAM-Mediterranean Agronomic Institute of Bari, Italy
- Trajkovic Slavisa, University of Nis, Serbia
- Tsunekawa Atsushi, Arid Land Research Center (ALRC), Tottori University, Japan
• Vurro Michele, National Research Council – Water Research Institute, Bari, Italy
• Yazar Attila, Çukurova University, Adana, Turkey
• Zairi Abdelaziz, INRGREF, Tunis, Tunisia
• Zazueta Fedro, University of Florida, Gainesville, USA and President of CIGR

CONFERENCE HONORARY COMMITTEE:

• Abu Zeid Mahmoud, President, Arab Water Council
• El-Beltagy Adel, President, CIHEAM, Paris, France
• Hamdy Atef, Emeritus Prof., CIHEAM-Mediterranean Agronomic Institute of Bari, Italy
• Santini Alessandro, Past President of Italian Association of Agricultural Engineers
• Sun Da-Wen, incoming President, CIGR

CONFERENCE ORGANIZING COMMITTEE:

• Huang Guanhua, China Agricultural University, Beijing, China, Chairman of CIGR Section I
• Lamaddalena Nicola, CIHEAM-Mediterranean Agronomic Institute of Bari, Italy
• Pereira Luis S., CEER, Institute of Agronomy, Technical University of Lisbon, Portugal
• Lebdi Fethi, Agricultural Water for Africa Coordinator (AgWA - FAO, Addis Ababa, Ethiopia
• Raeli Maurizio, Deputy Director, CIHEAM-Mediterranean Agronomic Institute of Bari, Italy
• Todorovic Mladen, CIHEAM-Mediterranean Agronomic Institute of Bari, Italy
Key Notes
Crop Evapotranspiration: the 15 years of FAO 56

Luis S. Pereira(1,*) and Richard G. Allen(2)

(1) CEER, Instituto Superior de Agronomia, Universidade de Lisboa, Portugal
(2) University of Idaho, Kimberly Research and Extension Center, Kimberly, Idaho, 83341, USA
(* Corresponding author Email: lspereira@isa.utl.pt

Abstract:

The FAO manual 56 on Crop Evapotranspiration has been published 15 years ago. A few good advances in evapotranspiration (ET) operational computations were then introduced including: a new definition and calculation procedures for computing the reference ET, an update on estimating crop coefficients (Kc), the adoption of dual Kc for separately estimating crop transpiration and soil evaporation, and an upgraded estimation of crop ET under water and salt stresses. These aspects are therefore reviewed and analysed.

The advances in computing the reference ET mainly refer to the adoption of a grass reference crop to parameterize the Penman-Monteith equation, thus definitely approaching the reference ET to a live reference crop and making crop coefficients more understandable as the factors that relate the studied crop with the reference crop. This also produced a new conceptual approximation when adopting alfalfa as a reference crop, thus making compatible computations with both reference crops. Advances in estimation methods when data sets do not include full weather variables are still slow because many researchers adopted a variety of equations as alternatives. However, methodologies already exist that permit an accurate estimation of the reference ET with only temperature data. The use of gridded variables is also possible.

Advances in Kc refer particularly to innovations in field data gathering and respective modelling. These advances include remote sensing and the use of surface energy balance models to estimate crop coefficients and crop ET, various approaches on the use of advanced micro-meteorological measurements over cropped or natural vegetation, and the appropriate use of water balance and water flux models calibrated and validated against soil water or evapotranspiration measurements. Advances are particularly interesting relative to the use of dual Kc modelling, which is allowing accurate estimation of soil evaporation and plant transpiration applied to both crops and natural vegetation. The adoption of a new approach relative to estimate dual Kc from plant density and height focusing partial cover crops as horticultural and fruit crops is a recent development that bases upon FAO56. The use of the yield response factor and of saline threshold values relative to a variety of crops is leading to appropriate definition of the water and salt stress coefficients that allow adjusting the crop coefficients and evapotranspiration to actual environmental conditions. However, there are still difficulties for many users in fully adopting the base concepts developed in FAO56 which may indicate areas where further efforts are required in future.

Keywords: reference evapotranspiration, crop coefficients, dual crop coefficient approach, evapotranspiration under non-standard conditions
Evapotranspiration Estimation with FAO56 Methodology: The Next Fifteen Years

Richard G. Allen\(^{(1,*)}\) and Luis S. Pereira\(^{(2)}\)

\(^{(1)}\) University of Idaho, Kimberly Research and Extension Center, Kimberly, Idaho, 83341, USA
\(^{(2)}\) CEER, Instituto Superior de Agronomia, Universidade de Lisboa, Portugal

\(^{(*)}\) Corresponding author Email: rallen@uidaho.edu

Abstract:

The crop coefficient (Kc) – reference ET (ET\(_{\text{ref}}\)) method supported and extended by FAO56 has been relatively successful and embraced by a broad range of users, spanning students, researchers, irrigation schedulers, water resources planners, and modelers. The method has filled an important need for producing accurate and controlled estimates of water consumption, while maintaining a simplicity that opens the computational process to a broad range of user backgrounds. The ‘two-stage’ method decouples day-to-day, weather-driven variation in ET represented by the reference ET from the day-to-day variation in ET controlled by the specific vegetation and its management. The isolated Kc and its Ks and Ke modifiers aggregate the influences of stage of growth of vegetation, planting date, season length, cultivar type, wetting frequency, soil water shortage, salinity or other stresses. The single Kc curve or set of curves and multiplicative adjustors have assisted the transfer of observation and research in ET and water consumption across regions and climates by normalizing ET data into the Kc curve. The Kc curve has assisted the development of universal computer models for water management and planning that are applied with a minimum of local information, for example, observation of planting or green-up dates and lengths of growing season. The global database of Kc will continue to grow to include new types or varieties of crops and natural vegetation. The expansion of the database will be assisted by spatial remote-sensing of fraction of ground cover and by ET produced by satellite-based surface energy balance. Future applications will rely more and more on thermal-time units such as growing-degree days to establish lengths of periods and the use of moving average air temperature to estimate planting or greenup dates. These bases will improve the translocation of Kc curves to new areas and for assessing the impacts of climate change. The Kc and ET\(_{\text{ref}}\) systems are increasingly applied with large gridded weather bases including the European Centre for Medium-Range Weather Forecasts (ECMWF), North American Land Data Assimilation System (NLDAS) and Global Land Data Assimilation System (GLDAS). These data sets are produced for the whole globe at 1 degree spatial resolution or finer and for specific regions at 12 km resolution. The Kc ET\(_{\text{ref}}\) approach functions well, symbiotically, with remote sensing-based methods that can extrapolate the methodology over large areas.

The Kc – ET\(_{\text{ref}}\) method may ultimately be replaced by more complicated and packaged ET estimation systems. However, it will probably continue to be used as a comparative estimate for QA/QC purposes and as a comparison base for new types of models and ET estimation methods for some indefinite time period. Because of the relatively good...
consistency and dependability of the Kc curves that have been developed for a large number of crops, globally, and the relatively good accuracy of ET estimates associated with the Kc - ETref method, when compared against accuracy of many measurements of ET, the Kc - ETref method is likely to remain in wide use over the next fifteen or so years.

*Key words:* evapotranspiration, state-of-the-art, crop coefficients, remote sensing
Managing water in agriculture under increasing scarcity: Need for a paradigm change

Theib Y. Oweis

International center for Agricultural research in the Dry Areas, ICARDA, Amman, Jordan
Email: t.oweis@cgiar.org

Abstract:

The dry areas, including the Mediteranian region, are experiencing severe and growing water scarcity. Its impact on food security and the environment, could potentially lead to socio-political instability and conflicts. Agriculture, the largest consumer of water, receives a progressively smaller proportion of the available water resources – while food demand continues to rise. It is therefore essential for water-scarce countries to produce more food with less water “more crop per drop”.

Conventional approaches to increase water productivity include; increase crop yields (increasing land productivity) while investing in modern irrigation systems and reducing water demand for agriculture. These approaches have major limitations. Higher crop yields generally require more water; modernizing irrigation systems, although increase the field and farm irrigation efficiency may not result in substantial and real water savings at the macro level; and pricing water for irrigation proved not to feasible, in developing countries, at least at the sociopolitical level.

In water-scarce areas, where water is more limiting than land, the focus must shift from increasing land productivity (yield per unit area) to maximizing water productivity, which is the returns (biological, economic, environmental, nutritional and/or social) per unit of water used. Research has shown that it is possible to double water productivity in the next 20 years. This is equivalent to doubling available water resources for agriculture. However, this will require strategic changes in cropping patterns, irrigation approaches, crop improvement, policies and institutions; and greater investment in research and capacity development.

Water productivity can be increased by increasing the productivity per unit of water consumed; by reducing non-beneficial water depletion; and by reallocating water among uses. In agriculture several practices can increase water productivity including improving crop water management and technologies such as deficit irrigation, supplemental irrigation and water harvesting. Simultaneously, countries may cultivate highly water productive crops while importing crops with high water demand and lower water productivity. Policy makers must make painful choices to rationalize water use while ensuring access to the poorest households.

Keywords: water productivity; land productivity; water policies; water scarcity
Assessing the productivity and resource-use-efficiency of underutilised crops: towards a integrative system

Sayed Azam-Ali(1,*) , Asha Karunaratne(1,2) , Sue Walker(1)

(1) Crops For the Future Research Centre, c/o University of Nottingham, Malaysia Campus, Jalan Broga, Semenyih, Selangor, Malaysia
(2) Faculty of Agricultural Sciences, Sabaragamuwa University, Belihuloya, 70140 Sri Lanka
(*) Corresponding author E-mail: sayed.azam-ali@cffresearch.org

Abstract:

CFFRC is the world’s first centre dedicated to research on underutilised crops for food and non-food uses. From its headquarters near Kuala Lumpur, Malaysia, CFFRC is building a global stakeholder alliance of education, public, private and civil society partners for research on underutilised crops. The alliance is underpinned by focussed research activities on underutilised crops based at CFFRC and at its international partner locations.

CFFRC research activities are focused around five ‘themes’ and six ‘programmes’. The themes provide a ‘Research Value Chain’ (RVC) of facilities and expertise on underutilised crops that spans the disciplinary sequence from fundamental plant genomics to applied social sciences viz.

Research Theme 1: Biotechnology and Breeding Systems
Research Theme 2: Crop Improvement and Agronomy
Research Theme 3: Agrometeorology and Ecophysiology
Research Theme 4: Agroprocessing and Bioproducts
Research Theme 5: Socioeconomics and Policy

The CFFRC research programmes each span the RVC to link genetic resources and specific end uses of underutilised crops viz.

BamYIELD: Bambara groundnut as an exemplar crop for Africa and Asia
BiomassPLUS: Novel biomass crops for sustainable renewable energy
SystemPLUS: Diversifying agricultural systems using underutilised crops and cropping systems

CropBASE: Web-based knowledge and decision-support system for underutilised crops.
FishPLUS: Novel plant products to increase the nutritional value of aquaculture feeds.
FoodPLUS: Diversification of the food basket for enhanced community nutrition and health.

CropBASE is a cross-cutting web-based platform for decision support and knowledge sharing on underutilised crops and their end uses. It provides a quantitative basis for comparison of underutilised crop productivity and resource-use-efficiency with that of major crops and cropping systems under current and future climate scenarios. To provide such comparisons, CropBASE is developing interactive tools to integrate novel data on underutilised crops with geo-referenced information in existing and new databases.
The main analysis engine of CropBASE will be specific crop application models. These include crop-climate, crop-quality and crop-economic models to assess the agroecological suitability, nutritional value and livelihood and food security potential of underutilised crops and their products at field, farm and regional scales. As crop-climate-crop modelling is currently at the most advanced stage, this will provide the initial impetus for the development of CropBASE. Various currently available climate databases will be linked to form a source of input data for the crop models, within a geospatial information system framework. CFFRC is already working with the crop modelling community (e.g. AgMIP www.agmip.org) and testing a number of major models for a range of crops around the world. CFFRC will spearhead the inclusion of specific underutilised crops into recognised crop models (APSIM, AquaCrop, DSSAT). After briefly introducing CFFRC and its constituent themes and programmes, this paper presents preliminary examples of predictions for yield and water productivity of bambara groundnut (an underutilised African legume) and pearl millet (a major cereal) under current and future climate scenarios in contrasting African locations

**Keywords:** underutilised crops, productivity, resource-use-efficiency, crop models
Landscape irrigation requirements and scheduling

Richard L. Snyder

Department of Land, Air and Water Resources, University of California, Davis, California, USA
Email: rlsnyder@ucdavis.edu

Abstract:

In recent years, there has been a concerted effort to improve urban water management to reduce non-recoverable losses while maintaining landscape quality. The WUCOLS method for determining landscape ET was the first widely promoted technique used in California. It uses standardized reference evapotranspiration (ETo), species coefficients, which depend on regional climate and drought tolerance, and empirical coefficients for plant density and microclimate. Later, the LIMP method was developed to address limitations in WUCOLS and to make landscape ET estimation less empirical. Perhaps the biggest difference between the two models is that the coefficients used in LIMP can be determined by scientific measurements. In LIMP, the species coefficient is separated into two coefficients: a maximum, well-watered vegetation factor and a stress factor. Plant density is based on the percentage ground cover in the LIMP method. Rather than empirically estimating microclimate effects, LIMP uses the ratio of local to regional ETo rates and topography to determine microclimate factors. The surface renewal method to estimate sensible heat flux from high frequency temperature data in combination with available energy data can potentially revolutionize our ability to estimate landscape evapotranspiration data on a micro-scale that will greatly improve our ability to determine the coefficients needed to employ the LIMP program and improve urban irrigation management. Some beta testing of this approach to measure landscape ET was recently conducted, and it will be presented in this paper. The potential impact of the LIMP program and new measurement techniques will be discussed.

Keywords: WUCOLS, LIMP, surface renewal, urban irrigation, evapotranspiration
Adaptation strategies for agricultural water management under climate change

Ana Iglesias(1,*) and Luis Garrote(2)

(1) Department of Agricultural Economics and Social Science, Universidad Politecnica de Madrid, Spain
(2) Department of Civil Engineering, Universidad Politecnica de Madrid, Spain
(*) Corresponding author Email: ana.iglesias@upm.es

Abstract:

This study links climate change impacts to the development of adaptation strategies for agricultural water management. Climate change is expected to intensify the existing risks, particularly in regions where water scarcity is already a concern, and create new opportunities in some areas. These risks and opportunities are characterised and interpreted across major European regions by reviewing over 100 highly relevant publications that appeared in the last decade. The result is a synthesis of the reasons for concern for global agricultural regions. The need to respond to these risks and opportunities is addressed by evaluating the costs and benefits of a number of technical and policy actions. The results highlight the importance of enhanced water use efficiency as a critical response to climate risks and the need for a more effective extension service. These results aim to assist stakeholders as they take up the adaptation challenge and develop measures to reduce the vulnerability of the sector to climate change. We propose a menu of adaptation strategies aiming to develop concrete adaptation plan and responding to concrete regional challenges. The greatest scope for action is in irrigation demands, however the implementation requires revamping current water policy, adequate training to farmers and viable financial instruments. A program of measures taking climate change into account should lead to an intensification of policies for demand management and supply enhancement derived from a more efficient water management.

Key words: adaptation, climate change, agricultural water management
Achieving ethical responsibilities in water management: a challenge

Giuseppe Rossi Paradiso

University of Catania, Executive Board of International Water Resources Association
Email: grossi@dica.unict.it

Abstract:

The problems of water management, including water scarcity, ecosystem degradation and water disasters vulnerability are expected to be exacerbated by global trends, as climatic changes, population growth, urbanization process and food uncertainty. Such a situation calls for a new awareness on the role of the international legal instruments and of common ethical principles to be recognized at world-wide level and applied at different local conditions. The lecture has two aims: first to review the efforts for reinforce legislation framework on water cooperation and on water rights and second to contribute to identify a set of ethical principles able to improve water governance and management at different levels. These principles - either drawn from the evolution of key-concepts within “water box” or derived from general environmental and social ethics - represent the basic perspectives for achieving ethical responsibility in water sustainable development and hydro-solidarity.

Keywords: legislation framework, water rights, water governance, hydro-solidarity
Session 1

Water use performance and water productivity
Yield and Water Use Efficiency of Durum Wheat Cultivars under Different Sowing Dates and Water Regimes

Abdalrhman Zoabi (1,*), Vito Cantore (2), Awadis Arslan (3), Vito Buono (1), Anna Maria Stellacci (4), Mladen Todorović (1)

(1) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
(2) Institute of Sciences of Food Production, CNR, Via Amendola, 122/O, 70125 Bari, Italy
(3) MAAR-GCSAR-ANRR, Damascus, Syria
(4) National Council for Agricultural Research, CRA-SCA, Via Celso Ulpiani 5, 70125 Bari, Italy
(*) Corresponding author Email: azoabi@hotmail.com

Abstract:

This study aims at understanding the best management practices to improve water use efficiency of durum wheat, a strategic crop for the Mediterranean region. A field work was carried out at the experimental fields of Mediterranean Agronomic Institute of Bari (IAMB) in Valenzano (Southern Italy), to investigate the performances of two cultivars (Vendetta and Pietrafitta) of durum wheat when grown under the combined effects of two sowing dates (December and February, reported respectively as winter and spring cultivation) and three different water regimes (full irrigation, deficit irrigation with 50% of full irrigation supply, and rainfed). The responses in terms of growth, yield and yield quality and water use efficiency have been studied.

The results demonstrated that both sowing practices gave very good yield, in terms of quantity and quality, especially when full irrigation was applied. The winter wheat cultivation resulted in greater yield water use efficiency (WUEy) than the spring wheat cultivation. ‘Vendetta’ was more productive than ‘Pietrafitta’, the latter was less adapted to spring cultivation and water stress.

Full irrigated wheat provided the highest yield, but lower WUEy in respect to deficit irrigated wheat. Favorable climatic conditions during the winter season supported a reasonable level of yield and high WUEy for rainfed crops sown in winter. Spring cultivation of wheat requires irrigation. Deficit irrigated wheat had the highest WUEy, showing that the use of non-optimal (supplemental) irrigation is a good strategy to improve yields of durum wheat in semi-arid areas and save water.

Keywords: Triticum durum, water use efficiency, water shortage, Mediterranean climate, Vendetta, Pietrafitta.
Assessing yield and water productivity of peas (*Pisum sativum* L. cv. Azarro) in a Mediterranean environment

Paula Paredes(1), Gonçalo C Rodrigues(1, 2), Luis S Pereira (1, *)

(1) CEER-Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Tapada da Ajuda, Portugal
(2) Cranfield Health, Cranfield University, Bedfordshire, MK43 0AL, UK
(*Corresponding author E-mail: lspereira@isa.utl.pt)

Abstract:

In Portugal, peas (*Pisum sativum* L.) are usually cropped during the Winter-Spring season, requiring only supplemental irrigation. However, more frequent irrigation and higher season water applications are required in dry years. When peas are for industry, irrigation is used to achieve a uniform flowering and a uniform maturation and size at harvest, i.e., high commercial yields. Thus, an adequate irrigation scheduling is needed to achieve high commercial yields.

The soil water balance model SIMDualKc, which applies the dual crop coefficient approach (Kcb + Ke) to compute the crop evapotranspiration (ET, mm), was calibrated and validated using available soil water (ASW, mm) data from two experimental plots located at farmers’ fields in the Ribatejo region, Portugal. The model calibration and validation was performed using crop, soil water content and meteorological data collected during the 2011 and 2012 irrigation seasons. During the 2011 irrigation season 2 plots were surveyed and in 2012 only one was seeded since peas require appropriate crop rotation. Peas in 2011 were seeded by 22 January and harvested by 3 and 5 May; in 2012 seedling took place at 19 January and harvesting was by 16 May.

Results relative to model calibration show a good agreement between ASW observations and model predictions, with low errors of estimate, e.g., RMS representing less than 4% of the total available water (TAW, mm) and high modelling efficiency, with the Nash and Sutcliff EF above 0.80. Results indicate that the model adequately predicts the soil water during the peas growing season.

The ET simulations were further used to test the Stewart’s model for assessing its accuracy to predict yields compared with field observations. In this application the potential crop yields (Ym, kg ha\(^{-1}\)) were estimated from regional climatic data using a modified approach of the ‘Wageningen’ method. The AQUACROP model was also tested for the same case study. Results show that both models may be used to predict peas yields. However, the first one requires less parameterization contrarily to the second and may be more useful for further use in farmers advising.

Water productivity (WP, kg mm\(^{-1}\)) at farm level may be used as an indicator for assessing the feasibility of alternative irrigation schedules. WP is defined as the ratio between the actual yield (Y\(_a\)) and the total water use (TWU) or the irrigation water use (IWU) if considering irrigation only. For the various plots, TWU was estimated using the actual gross irrigation depths applied by the farmer for different irrigation schedules, the precipitation (mm) and the difference in soil water content between planting and harvest (ΔSW, mm); the latter was obtained with the calibrated SIMDualKc model. WP ranged
from 24.2 to 32.6 kg mm\(^{-1}\) in 2011 and reached 19.0 kg mm\(^{-1}\) in 2012. This study shows that the modelling approaches herein applied are useful to support farmers’ advice.

**Keywords**: crop evapotranspiration, dual crop coefficients, soil water balance, irrigation scheduling, simulation modelling
Modelling evapotranspiration of seed propagated Globe Artichoke in a Mediterranean environment

Vito Cantore(1,*), Mladen Todorovic(2), Maria Immacolata Schiattone(2), Francesca Boari(1)

(1) Institute of Sciences of Food Production, CNR, Via Amendola, 122/O, 70125 Bari, Italy
(2) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
(*Corresponding author E-mail: vito.cantore@ispa.cnr.it

Abstract:

This work aims at improving the estimation of artichoke evapotranspiration in Mediterranean climates through the modelling of crop coefficients (Kc) and duration of phenological phases of a seed propagated artichoke. A two years trial was carried out at the experimental station "E. Pantanelli" of University Aldo Moro (Bari), located in the countryside of Policoro (MT), southern Italy. The seed propagated artichoke cv. 044 was grown in two weighing lysimeters placed in a large field and watered regularly. The irrigation was applied when 40% of total available water in the soil layer occupied by roots was consumed which corresponded to the crop evapotranspiration (ETc) between 25 and 40 mm. Irrigation was applied in such a way to replenished completely the depletion of water in the root zone. The reference evapotranspiration (ETo) was computed daily, by using Penman-Monteith equation from the weather data collected at the agrometeorological station near the experimental field. The growing season started in mid of July and ended in the second part of May. The artichoke crop cycle was 310 and 313 days in the 1st and 2nd year, respectively. Average seasonal ETc measured at two lysimeters was slightly higher in the 1st year (967 mm) than in the 2nd one (911 mm). Water use obtained in this trial was 85% higher than usually reported in the literature for vegetatively propagated crops in the same area and with similar crop length. Most likely this was due to taller crops (1.7 m) and higher biomass production in seed propagated crop. Crop coefficients (Kc), calculated daily as the ratio between ETc and ETo, revealed that five phenological stages could be considered in ETc estimate: i) the seedling establishment of about 30 days; ii) the initial development phase of approximately 60 days; iii) winter vegetative stagnation of approximately 90 days; iv) spring recovery of about 90 days, and v) full development stage of about 45 days. The Kc values during the seedling establishment were between 0.3 and 0.4 and increased up to 0.8-0.9 at the end of initial development period. The Kc values were reduced gradually to 0.4 at the end of winter vegetative stagnation and then increased up to 1.1 during the full development period. The presented results differ from those available in the literature since they refer to a seed propagated artichoke which is taller and more vigorous than vegetatively propagated crop. In the last years, the former crop tends to substitute the later one in many Mediterranean areas and a proper crop evapotranspiration estimate and irrigation management are of crucial importance for a more efficient water use in the region.
Further efforts could focus on the introduction of the growing degree days concept and substitution of sum of days with thermal sums as well as on the link between Kc and leaf area index (LAI).

**Keywords:** Cynara cardunculus, crop coefficient, development stages, crop evapotranspiration.
Water use and crop coefficients of celery and fennel in Mediterranean environments

Francesca Boari(1*), Mladen Todorovic(2), Maria Immacolata Schiattone(2),
Vito Cantore(1)

(1) Institute of Sciences of Food Production, CNR, Via Amendola, 122/O, 70125 Bari, Italy
(2) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
(*) Corresponding author Email: francesca.boari@ispa.cnr.it

Abstract:

A ratio of crop evapotranspiration (ETc) to reference evapotranspiration (ETo) determines a crop coefficient (Kc) value, which is related to vegetation growth and specific crop phenological development. The determination of Kc is important for predicting crop irrigation needs using meteorological data from weather stations. The objective of the research was to determine growth-stage-specific Kc and crop water use for celery and fennel using the experimental data from C.D.S. ‘E. Pantanelli’ of University Aldo Moro of Bari, located in the countryside of Policoro (MT), southern Italy. Two weighing lysimeters, consisted of undisturbed 4 m² area of 1.5 m depth of soil monoliths, were utilized to measure crop water use. The lysimeters were located in the center of a 0.5 ha field of square form. Water use was measured on a daily basis. In addition, daily reference evapotranspiration (ETo) was computed by the Penman-Monteith equation, utilizing the weather data collected at the agro-meteorological station near the experimental field. Watering was provided with drip method and scheduled to keep soil water content in the root zone under optimal growing conditions (irrigating at 20% of available water depletion and restoring 100% of the ETc measured daily by lysimeters). The length of crop cycle was 110 and 117 days for celery, and 93 and 135 days for fennel, in the 1st and 2nd year, respectively. For celery, the total ETc amounted to 231.5 and 313.3 mm in the 1st and 2nd year, respectively, and daily Kc ranged between 0.4 and 1.4. For two cultivars of fennel, whose growing cycle took place at different times of the year (August-September-February ‘Trevi’), the total ETc was equal to 311.7 mm for ‘Conero’ and 249.8 mm for ‘Trevi’. The daily Kc varied between 0.4 and 1.9 for ‘Conero’ and between 0.5 and 1.7 for ‘Trevi’. Specific Kc values across the growing season were determined based on the Kc curves that represent the distribution of Kc over time throughout the season. Hence, it can be highlighted that the values of Kc corresponding to the three typical phenological stages (initial, mid-growth, final) of celery were about 10% higher than those reported in FAO 56 Irrigation and Drainage Paper. The Kc was modelled as a function of days after planting and growing degree days. The later could be more useful for practical applications since reduces the necessity of frequent field observations of phenological phases. The development of regionally based and growth-stage specific Kc curves helps in irrigation management and
provides a tool for a better water use in arid and semi-arid areas of the Mediterranean region.

**Keywords:** *Apium graveolens, Foeniculum vulgare, weighing lysimeter, evapotranspiration, crop coefficient Kc, heat units.*
Dual crop coefficient modeling applied to soybean: basal crop coefficients and soil evaporation component

Zheng Wei\(^{(1,2)}\), Yu Liu\(^{(1,2)}\), Wei Wei Chi\(^{(1)}\), Paula Paredes\(^{(3)}\), Luis S. Pereira\(^{(3,\ast)}\)

\(^{(1)}\) State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing 100038, China
\(^{(2)}\) National Center of Efficient Irrigation Engineering and Technology Research, Beijing 100048, China
\(^{(3)}\) CEER-Biosystems Engineering, Institute of Agronomy, University of Lisbon, Tapada da Ajuda, 1349-017 Lisbon, Portugal
\(\ast\)Corresponding author E-mail: lspereira@isa.utl.pt

Abstract:

The main objective of this study was to calibrate and validate the SIMDualKc model for soybean using four successive years of field experimental data. The calibration procedure aimed at obtaining the basal crop coefficients, the soil evaporation parameters used to compute the evaporation coefficient (K_e), and the soil water depletion fraction for no stress (p) that minimize the differences between observed and simulated available soil water values relative to the entire root depth profile. The calibrated Kcb values for soybean were 0.15 for the initial stage, 1.05 for the mid-season and 0.35 at harvesting. Model results show a good agreement between available soil water data observed and predicted by the model, with root mean square errors of estimates (RMSE) of approximately 9.8 mm for both the calibration and validation which corresponds to approximately 5% of soil total available water (TAW). The modeling efficiency (EF) and the index of agreement (dIA) were larger than 0.66 and 0.88, respectively, thus indicating good performance of modeling with SIMDualKc. The model was also verified on the basis of predicting soil evaporation, which was measured with microlysimeters installed along the crop row; the respective RMSE averaged 0.41 mm d\(^{-1}\) obtained from four years of observations. Results for soil evaporation allowed confirming the appropriateness of the SIMDualKc model to estimate soil evaporation of a cropped soil. The model and the dual Kc approach might be further used to develop improved irrigation schedules for soybean in North China.

Keywords: SIMDualKc model, transpiration, soil evaporation, microlysimeters, soil water balance
Accurate large-scale irrigation performance assessment with a poor dataset

Nicolas Feltz(1,*), Marnik Vanclooster(1)

(1) Earth and Life Institute, Université catholique de Louvain, Belgium
(*)Corresponding author E-mail: Nicolas.Feltz@uclouvain.be

Abstract:

Irrigated agriculture remains the largest consumer of global freshwater resources, and improving water management in irrigated agriculture is a key issue to solve the global water and food crisis. The design, planning and improvement of irrigation often rely on the assessment of irrigation performance (IP), using efficiency indicators. However, the use of the efficiency concepts can lead to misinterpretation and is frequently criticized. Moreover, they only include technical, on-site and time-specific considerations, while socio-economic issues, management and scale effects are neglected. Large scale irrigation performances are then likely to differ from reference on-site efficiencies and specific methodologies needs to be implemented to evaluate them.

In this research, we aim to assess and model technical and large-scale irrigation performance for the Triffa’s irrigation perimeter in East Morocco, subjected to different irrigation development scenarios. The objectives are to characterize the irrigation long term technical performance at perimeter level and to improve the understanding of factors influencing this performance.

The performance is based, among others, on the calculations of the water balance at the perimeter scale. Since, in the study area, as in many irrigation perimeters around the world, data availability and data quality is often poor, a two-step modelling approach was developed to assess the perimeter water balance and to optimise data collection as a way to improve the accuracy of the performance assessment.

In a first modelling step a simple reservoir based water balance model was implemented. Widely available background data (land use and land use pattern, soil data, topography, water table level, meteorological data...) were collected and used to run this model and a very basic validation step was processed. The most sensitive parameters were subsequently identified using a formal sensitivity analysis. The sensitive components of the conceptually based reservoir model were then refined. In addition, a field campaign was performed for collecting data for the sensitive components with the required accuracy. This second model was finally used to assess performance indicators.

The first model included 20 parameters. The sensitivity analysis identified 6 parameters of major importance. Those parameters were linked to irrigation practices (field-scale performance of irrigation of the three main crops and the ratio between irrigation water coming from the water table and from the official irrigation system, i.e. water diverted from the river) and to water table characteristics (transmissivity and porosity of the aquifer). Aquifer characteristics were collected...
from pumping tests records in the archives of the appropriate administration. A particular attention was devoted to the uncertainty associated to those data. Furthermore, a specific model was designed to represent irrigation practices from easily available data. This specific model has been validated in itself before integration in the global model. Both measurements and data collection procedure implied, in total, two field campaigns of two weeks each. This study therefore shows that perimeter-scale performance assessment can be performed at a reasonable cost with good accuracy. Since data availability and quality is a major constraint for assessing performance of many irrigation perimeters around the world and data collection is usually very expensive in terms of time and money, our two step procedure allows minimizing this cost by means of a preliminary identification of the most meaningful data.

**Keywords**: Irrigation performance assessment, Irrigation perimeter, Water cycle, Data collection, Scale effects
Response of water status indicators to water stress in olive tree

Kanako Nitta\(^{(1)}\), Koji Inosako\(^{(1,\ast)}\), Mladen Todorovic\(^{(2)}\), Vito Buono\(^{(2)}\)

\(^{(1)}\) Tottori University, 101-4,Koyama-minami,Tottori,680-8553, Japan,
\(^{(2)}\) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, Valenzano, Italy
\(^{(*)}\) Corresponding author E-mail: inosako@muses.tottori-u.ac.jp

Abstract:

Olive tree (Olea europaea L.) is considered as one of the oldest species and the crop well-adapted to the Mediterranean environment. However, due to climate change, irrigation is becoming an imperative to sustain olive’s cultivation. Thus, it is important to evaluate the level of water stress by measuring olive’s tree water status. In this study, physiological responses of olive were monitored to clarifying behaviour of each water status indicator to water stress through a series of continuous measurements. Four water status indicators, soil water content, tree stem water content, sap flow and leaf conductance were observed under irrigated and rainfed conditions. In addition, some observations on olive trees were performed in order to evaluate the relative effect of irrigation on plant growth.

The experiment was conducted at an experimental field of the CIHEAM-IAMB in Italy from March to September 2012. The difference in response of olive trees under two water regimes was significant in terms of four water status indicators. The experimental period was divided into three phases: without stress, when the condition started to change because of the irrigation application, and when water stress was first detected. The water status indicators responded differently to both the application of water (by irrigation) and the moment in which water stress appeared. A sort of “critical point” of the soil water content for olive was detected for this field, and it was consistent with the one calculated from the retention curve according to the FAO I&D Paper 56. The corresponding values of water status indicators were found to be clearly correlated within each other, following similar paths and trends for both water regimes until a critical value of the soil water content was reached. Close to this point, all the plant water status indicators showed a clear trend of reduction to minimal values. In biometric observations, there were the differences of the growth of olive tree between irrigated and rainfed treatments (leaf area and fruit establishment).

The changes in the physiological responses of olive trees under irrigated and rainfed conditions can be evaluated by means of integrated observations of the water movement in soil-plant–atmosphere continuum. The indicators such as the tree stem water content and/or the sap flow could be effectively used to evaluate the occurrence of water stress in olive, better in relation with additional data on soil water content and/or the evaporative demand of the atmosphere. The effectiveness of irrigation strategies to avoid water stress can be confirmed by the use of such indicators.

**Keywords:** Soil water content, Tree stem water content, Sap flow, Leaf conductance
“WP_optimizer” to improve water productivity in irrigated agriculture in Egypt

Samar M. Attaher(1,*), Nahla Zaki (2) and Muhammed Karrou (3)

(1) Agriculture Engineering Research Institute, Agriculture Research Center, Dokki-Giza-Egypt.
(2) Water Management Research Institute, National Water Research Center, Kanater-Kaliubia- Egypt.
(3) International Center for Agricultural Research in the Dry Areas (ICARDA).
(*) Corresponding author E-mail: sattaher2001@yahoo.com

Abstract:

Water scarcity and salinity are major problems associated with the irrigated agriculture in the dry areas. The aim of the modeling activity in Egypt is to develop an appropriate tool to help in designing possible efficient, economic and sustainable irrigation strategies that maximize water productivity and minimize environmental harmful impacts. In the current case study, a comprehensive analysis of a tertiary canal system has focused on two scales, the on-farm level, and irrigation distribution network. The modeling work started with reviewing the different methodologies and tools that could be used in the current case study. Both the on-farm water management model and the water balance model are linked together in an integrated modeling framework called “Water productivity optimizer (WP_optimizer) which is under development now by using VB language, to be worked under GIS environment. WP_optimizer is designed to work in two modes; “evaluation” mode, and “scenario builder” mode.

“SaltMed” is the on-farm water management model, which is selected to analyze water balance at the crop level (homogenous unite), in order to give better indications of crop-water consumption, crop-soil-water interactions, salinity build-up at the root zone, and then to determine crop water-productivity. The outputs of SaltMed for each homogenous unite (crop transpiration, evaporation, infiltration..etc), are the inputs of the “up-scaling water-balance” model to represent the root zone system and irrigation demands at the farm level. The up-scaling water-balance model is starting from root-zone system water balance, moving to water-balance at the irrigation distributary network, the overall water productivity, and the distribution equity inside the command area.

The current version of the WP_optimizer, is based on some important boundary assumptions; (i) the soil type at the tertiary canal system is the same, (ii) the time step of the analysis is 15 days (to match irrigation rotation system), and (iii) the smallest unit of analysis is “mesqa” command area with a crop pattern represented as a percent of the area of each crop (due to the availability of the data at the current conditions). These assumptions will be verified in the next versions of the models using real data and information. In this paper, the integrated modeling methodology and framework development is described and discussed.

Keywords: water management model, water balance model, SaltMed,
Effect of different fertilization and irrigation methods on nitrogen uptake, water and radiation use efficiency of okra grown in the Keta sand spit, Ghana

Eric Oppong Danso(1), Stephen Abenney-Mickson(1), Edward Benjamin Sabi(1), Finn Plauborg(2), Yvonne Ohui Kugblenu(3), Christian Richard Jensen(4), Mark Abekoe(5) and Mathias Neuman Andersen(2)

(1) Agricultural Engineering Department, University of Ghana, Accra, Ghana, (2) Department of Agroecology, Faculty of Science and Technology, Aarhus University, Tjele, Denmark, (3) Crop Science Department, University of Ghana, Accra, Ghana, (4) Department of Agriculture and Ecology, Faculty of Life Sciences, University of Copenhagen, Taastrup, Denmark, and (5) Soil Science Department, University of Ghana, Accra, Ghana

(*) Corresponding author Email - sujaniyaayaa@yahoo.com

Abstract:

Okra (Abelmoschus esculentum L.) is widely grown in the Keta sand spit area in southeast Ghana. The farmers in the Keta sand spit have been applying high amounts of nitrogen (N) fertilizers and frequent irrigation at high rates on sandy soils with low inherent water and nutrient retention capacities. The long term viability of a shallow groundwater lens which is used for irrigation in the area is threatened by several consecutive years of over withdrawal. With rising concern about current irrigation and fertilizer management, the present study was conducted to evaluate the effect of different irrigation and fertilization methods on nitrogen uptake, radiation use efficiency and water use efficiency of okra grown in a sandy soil. A three season study was carried out to determine the okra crop response to the following treatments: 1. sprinkler irrigation with spread manure (SSM); 2. sprinkler irrigation with placed manure (SPM); 3. drip irrigation with placed manure (DPM) and 4. drip irrigation with fertigation (DFT). Fertigation was done only two times (two weeks after germination and immediately after flowering) during the first experiment while weekly fertigation (8 times from two weeks after germination) was done during the second experiment. Results from the experiments showed that the okra crop did not respond well when fertigation was done only twice (two weeks after germination and immediately after flowering) in the first experiment, probably due to nitrogen lost through leaching on a sandy soil. However, the second and third experiments showed a marked improvement in the fertigated treatment compared to the others when fertigation was done weekly for eight weeks. In the second experiment, though nitrogen applied was the same (89 kg N/ha), for all treatments, the highest N uptake, water use efficiency (WUE) and radiation use efficiency (RUE) were obtained under DFT and these parameters were significantly (P≤0.05) higher than the other treatments (SSM, SPM, and DPM). However, an increase in fertilization in the third experiment (from 89 kg N/ha to 140 kg N/ha) caused no significant (P≤0.05) difference in N uptake and RUE for all the treatments but WUE of DFT and DPM were significantly higher than SSM and SPM. Drip irrigation treatments (DPM and DFT) saved close to 30% water compared to sprinkler irrigation treatments (SSM and SPM). From the results it is concluded that drip irrigation with
frequent fertigation resulted in more efficient use of nitrogen, water and radiation than obtained with sprinkler irrigation.

Keywords: *drip irrigation, sprinkler irrigation, fertigation, sandy soil, cow dung.*
Effect of Two Different Irrigation Techniques and The Application Of The Partial Root Zone Drying Technique on Potato Crop

Ihab Jomaa(1,*) , Mohamad Younes(2), Elie Harfouche(3), Sleimen Skaf(1);
Randa Massaad(1) Oussama Monzer(4)

(I) Irrigation and AgroMeteorological Department, Lebanese Agriculture Research Institute, Tal Amara, Ryak, 287 Zahle, Lebanon
(2) Rural Development Department, Litani River Authority, 1P.O.Box: 13732 Bir Hassan, Beirut, Lebanon
(3) Research and Development Department, Debbane Fréres SAL, P.O. Box 11-9666 Beirut, Lebanon
(4) Centro de Edafología y Biología Aplicada del Segura-Consejo Superior de Investigaciones Científicas (CEBAS-CSIC), Spain
(*)Corresponding author E-mail: ijomaa@lari.gov.lb

Abstract:

Highly sensitive to water shortages, potato crop is widely planted and in three different seasons across Lebanon. In 2011, experimental trials of early and late spring potato seasons were conducted at the Lebanese Agricultural Research Institute of Tal Amara (LARI) to investigate plant response to two irrigation systems (mini-sprinkler and T-tape) with the application of the Partial Root Zone Depletion regimes (PRD). Spunta potato variety, largely grown over the country, was cultivated with treatments of three irrigation regimes: (1) T_0 (mini-sprinkler) and (2) T_1 (T-tape drip) treatments were irrigated with the full water requirement by plants or 100% of crop evapotranspiration (ETc), and (3) the third treatment T_2 (T-tape) was irrigated with only 50% of the plant water requirements, starting from tuber initiation-phenological stage. Water requirement were determined using a nearby weather station and through the computation of reference evapotranspiration (ETo). Water evapotranspiration throughout the season has reached about 550mm. Rooting depth has fitted previous studies in relation to the growing degree days (GDD), which indicate the possibility to follow this trend of root evolution in the area of the experiment for crop modeling purposes. Root development has demonstrated horizontal spreading in mini-sprinkler system where the water uptake has been concentrated mainly in the upper 20 cm of soil depth. Drip system of T_1 had shown a root water uptake in the first 30 cm of soil. For PRD, the root system tends to uptake water from deeper soil horizons. The stem water potential reading has indicated higher leaf water potential (-0.6Mpa to 1 Mpa) for the PRD trial in comparison to the other treatments. Mini-sprinkler (T_0) and drip irrigation (T_1) had demonstrated no significance difference in tuber yield with about 0.56 and 0.504 t/ha respectively. PRD influenced tuber yield (P < 0.05), and reaching 0.28 t/ha. Cost surveys and farmer questioning have demonstrated that the installment cost by hectares is 7100$ and 9100$ for drip and sprinkler systems respectively. Drip irrigation applies less water per crop which decreases fuel consumption. PRD requires further investigations using drip
irrigation techniques and in different plant phenological stages in order to establish the optimum water application requirements.

**Keywords:** Min-sprinkler, T-tape drip, PRD, Evapotranspiration, farmers' input cost.
The influence of feeding strategies on water productivity in dairy farming

Michael Krauß(1,*), Simone Kraatz(1), Katrin Drastig(1)

(1) Leibniz Institute for Agricultural Engineering Potsdam-Bornim, Max-Eyth-Allee 100, 14469 Potsdam, Germany
(*)Corresponding author E-mail: mkrauss@atb-potsdam.de

Abstract:

The growing world population and the change in diets to include more animal products will lead to escalating demands on global resources for food production. Competition for resources between agriculture, industrial and domestic uses will increase. In order to meet these challenges of global change, agricultural practices must be improved to increase resource efficiency. Water’s vital role as a major resource in agricultural production is driving the current search to improve water productivity. The objective of this work is to quantify the effect of management strategies in livestock farming on water productivity at the farm-scale. In order to do this, a method is being developed to quantify the water use of farming systems, including both direct and indirect water flows and uses. The investigations are being carried out in dairy farms, since dairy farming is the most complex type of livestock operation, involving the production of plants, milk and meat.

The present study focuses on the water productivity for feed supply (WPfeed), since plant production accounts for the main share of water use in dairy farming. The water productivity of milk (WPmilk) is calculated as the amount of water needed to produce the feed required to reach the nutrient-demand for milk yield and maintenance. The functional unit WPmilk is kg fat-corrected milk per m³ of direct and indirect water use (kg FCM/m³ water). Diet ingredients are grass-silage, maize-silage, hay, pasture, beet-pulp-silage, soybean meal, rapeseed meal, grain and concentrate. Recommendations for preferred solutions to decrease water use in milk production are developed, considering the influence of feeding strategies and milk yield. The feeding strategies are based on the maximization of certain ingredients, such as grass-silage, maize-silage, pasture and concentrate. The milk yield is varied between 4000 and 12000 kg fat-corrected milk (FCM) per cow and year in steps of 2000 kg. The composition of the diet is varied in accordance with nutritional aspects. The calculation is made for the years 2008 to 2010 for conditions in North-East-Germany, except for soybeans, which were grown in Argentina and Brazil. The WPfeed of each crop is calculated using the sum of the actual transpiration over the growing period of the plant related to the crop yield. The functional unit is kg dry matter (DM) feed/m³ water.

Grass-silage and maize-silage had a WPfeed of 4.7 and 2.6 kg DM/m³ water and grain between 1.0 and 1.6 kg DM/m³ water. Soybeans had a WPfeed of 0.5 kg DM/m³ water. The cow with 8000 kg FCM per year and grass-silage based feeding had the highest WPmilk (3.3kg FCM/m³ water). The lowest WPmilk (1.9kg FCM/m³ water) was found for the same cow with maize-silage based feeding.
The results showed that the $W_{P_{\text{milk}}}$ increases within all milk yields with an increasing proportion of grass-silage and pasture in the diet. The milk yields of 8000 and 10000 kg FCM were most beneficial related to water productivity. Therefore, the recommended system for milk production in North-East-Germany in order to achieve the highest $W_{P_{\text{milk}}}$, is one that aims for a milk yield between 8000 and 10000 kg FCM per cow and year with grass-silage based feeding.

**Keywords:** water productivity, milk yield, feeding strategy, farm-scale
Tangor “Ortanique” Response to Soil Water Regime

Cánepa Pancracio(1,*), García Mario(2)

1 Soil and Water Department, University of the Republic, Rivera 1350, Salto, Uruguay
2 Soil and Water Department, University of the Republic, Av. Garzón 781, Montevideo, Uruguay
* Corresponding author E-mail: pecanepa@adinet.com.uy

Abstract:

Tangor Ortanique (C. sinensis [L.] Osb. × C. reticulata Bl.) response to soil water regimes using mole drain and furrow irrigation was evaluated for three years. Orchard soil is a Typic Hapludert. Trial had split-plot design; main plot was drainage or not drainage each one divided into irrigation or not irrigation. Mole drain was no effective and differences in soil water regimes were due to irrigation. At the end of the trial irrigated trees had greater trunk diameter, drainage-irrigation had greater canopy volume, drainage without irrigation the least, and treatments without drainage intermediate values. Irrigation diminished water stress intensity and duration but did not improve fruit production. Water stress did not explain low fruit set, critical problem for this cultivar. Some most limiting factor inhibits the expression of the potential benefits of irrigation. High blooms every year cause an imbalance source-sink relationship and high temperatures during fruit set ocor. One or both of these facts could explain low fruit set and low fruit production.

Keywords: Citrus, irrigation, drainage.

Keywords: Tangor Ortanique, mole drain, furrow irrigation
Session 2
Conservation agriculture
and water saving
WADIS-MAR - Water harvesting and Agricultural techniques in Dry lands: an Integrated and Sustainable model in Maghreb Regions

Giorgio Ghiglieri\(^1\), Gabriela Afrasinei\(^1\), Claudio Arras\(^1\), Mohamedou Oulb Baba Sy\(^1\), Manuela Barbieri\(^1\), Oumelkheir Belkheiri\(^1\), Mongi Ben Zaied\(^6\), Cristina Buttau\(^1\), Alberto Carletti\(^2\), Abdelkader Dodo\(^7\), Giuseppe Enne\(^2\), Antonio Funedda\(^1\), Ileana Ioccola\(^2,3\), Luigi Ledda\(^2\), Roberta Lobina\(^2\), Elhadj Meftah\(^5\), Maria Teresa Melis\(^4\), Abdelouhab Messaudane\(^5\), Kamel Nagaz\(^6\), Arezki Ouldamara\(^5\), Mohamed Ouessar\(^6\), Daniele Pittalis\(^5,3\), Pier Paolo Roggero\(^2\), Mouski Said\(^5\), Mongi Sghaier\(^6\), Albert Soler i Gil\(^4\), Rachid Taibi\(^5\), Clara Torrento\(^4\), Salvatore Virdis\(^2\), Chiara Zanolla\(^2\), Houcine Yahyaoui\(^6\), Abderezak Zahrouna\(^5\)

\(^1\)Department of Chemical and Geological Sciences, University of Cagliari, Via Trentino 51 - 09127 Cagliari, Italy (ghiglieri@unica.it)
\(^2\)Desertification Research Center – NRD, University of Sassari, Viale Italia 39 - 07100 Sassari, Italy (nrd@uniss.it)
\(^3\)InTReGA S.r.l., ENEA Spin-off, Piazza S. Ruiu 2, 07100 Sassari, Italy (info@intrega.it)
\(^4\)Departament de Cristallografia, Mineralogia i Dipòsits Minerals Facultat de Geologia, c/Marti i Franquès s/n - 08028 Barcelona, Spain (albertsolergil@ub.edu)
\(^5\)Agence Nationale des Ressources Hydrauliques – ANRH, 40 Avenue Mohammedi, Bir Mourad Rais – Alger, Algeria (anrh@anrh.dz)
\(^6\)Institutes des Région Arides - IRA, Route du Djorf Km 22.5 Médenine, Tunisie (Ouessar.Mohamed@ira.rnrt.tn)
\(^7\)Observatoire du Sahara et du Sahel – OSS, Boulevard du Leader Yasser Arafat BP 31 Tunis Carthage 1080 Tunisie (lamine.babasy@oss.org.tn)

(*)Corresponding author E-mail: ghiglieri@unica.it

Abstract:

North Africa arid land of Maghreb, suffer scarce water conditions. Erratic behavior of rainfall events over brief intervals often produce short and intense floods events which converge into ephemeral wadi beds. Most part of the available superficial waters is thus lost, providing scarce benefits for households living in villages of such semi-desert areas.

WADIS-MAR is one of the five Demonstration Projects implemented in the framework of the Regional Programme “Sustainable Water Integrated Management (SWIM)” that is funded by the European Commission and aims to contribute to the effective implementation and extensive dissemination of sustainable water management policies and practices in the Southern Mediterranean Region. The Programme has been designed in the context of increasing water scarcity, combined pressures on water resources from a wide range of users, desertification processes and climate change impacts.

WADIS-MAR Project (2012-2014) concerns the realization of an integrated water harvesting and artificial aquifer recharge techniques in two watersheds in Maghreb Region: Oued Biskra in Algeria and wadi Oum Zessar in Tunisia. These areas are
characterized by water scarcity, overexploitation of groundwater resources and highly exposed to climate change risk and desertification processes.

The WADIS-MAR Project, taking into account past local traditional experiences, will implement a sustainable water and agriculture management system based on participative and bottom-up approach to enable local communities to manage groundwater resources, starting from a more efficient water harvesting techniques (WHT) and a sustainable agricultural practices application. In this work are reported the main first year activities and results achieved.

**Key words:** Artificial aquifer recharge, Water Harvesting, Best Agricultural Practices, Desertification, Maghreb Regions
Co-design of innovations for sustainable small-holder irrigation: The EAU4Food project case study in South Africa

Nebo Jovanovic(1,*), Constansia Musvoto(1), Willem De Clercq(2), Andrei Rozanov(2), Cou Pienaar(2), Nathaniel Mason(3), Brilliant Petja(4), Jochen Froebrich(5), Erik Querner(5), Jannike Wichern(5), Xueliang Cai(6)

(1) CSIR Natural Resource and Environment, PO Box 320, Stellenbosch 7599, South Africa
(2) University of Stellenbosch, Dept. of Soil Science, Private Bag X1, Matieland 7602, South Africa
(3) Overseas Development Institute, 203 Blackfriars Road, London SE1 8NJ, United Kingdom
(4) Limpopo Provincial Department of Agriculture, Private Bag 9487, Polokwane 0700, South Africa
(5) Wageningen UR - Alterra, 6708 PB Wageningen, The Netherlands
(6) International Water Management Institute, 141 Creswell Street, Pretoria 0184, South Africa
(*Corresponding author E-mail: njovanovic@csir.co.za

Abstract:

Growth in agricultural production in Africa has generally lagged behind that of the rest of the world and will be increasingly challenged by threats from climate change, water scarcity, environmental degradation, and competition for scarce energy resources. New approaches are therefore required to increase food production in irrigated areas in Africa, while ensuring healthy and resilient environments. The EAU4Food project (European Union and African Union cooperative research to increase food production in irrigated farming systems in Africa) seeks to address these challenges in four irrigated zones in Africa (Mozambique and South Africa, Tunisia, Mali and Ethiopia). The aim of this paper is to present the participatory process of co-designing innovations for increasing food production in small-holder farms at the South African study site. Many previous attempts to increase food production in irrigated areas resulted in poor uptake of scientific knowledge and technologies, due limited involvement of stakeholders, ill-understood socio-economic structures and/or mono-disciplinary approaches. The research team utilized a trans-disciplinary approach through the establishment of learning practice alliances (LPAs) and communities of practice (CoPs) in order to: i) identify problems; ii) identify solutions; iii) co-design innovations; iv) demonstrate innovations. Based on the outcomes of LPA and CoP participative actions, the following top priority problems/constraints were identified by farmers and stakeholders: 1) Lack of equipment; 2) Farm management; and 3) Marketing. Three potential solutions were proposed: 1) Improvement of crop yields, water and energy efficiency; 2) Conservation of soil fertility and water; 3) Reduction of secondary problems such as salinity and nutrient losses. Innovations were soil profile preparation and scientific irrigation scheduling for solution 1, application of locally-produced soil organic amendments for solution 2, and scenario modelling with calibrated hydrological models to predict large scale impacts of innovative irrigation and fertilization practices.
for solution 3. As a result of these findings, a cropping system was proposed with at least three harvests per year under irrigation (tomato), by making use of favourable climatic conditions (sub-tropical climate with summer rainfall season), to secure a steady income to the farmers and a steady supply of products to the local markets. Demonstration experiments in Giyani District (Limpopo Province) indicated that tomato yields commonly achieved on small-holder farms (15-20 t ha$^{-1}$) are well below their potential (40-70 t ha$^{-1}$), due mainly to incorrect water application and fertilization below the recommended quantities due to the high cost of fertilizer. Organic mulching experiments demonstrated the benefits of reduced water use and addition of organic amendments. Scenario modelling with the SIMGRO and SWAT hydrological models indicated that sustainable agriculture can be practiced in large areas of the environmentally-sensitive and water-stressed Letaba catchment without detrimental impacts to downstream water users (drinking water supply, farmers, industry, environmental flows in the Kruger National Park and users in Mozambique). The robustness of the co-designed innovation process and demonstration actions is expected to have significant positive impacts on small-holder agricultural production for many years to come.

**Keywords:** food security, irrigation management, small-holding farms, soil fertility, trans-disciplinary approach.
Effects based on Soil and Water Storage of Water harvesting practices

Meryem Kuzucu (1), Funda Dökmen (2,*), Ayşe Güneş (3)

(1) Pistachio Research Station Directorate, Gaziantep, Türkiye.
(2) Kocaeli University, Food & Agricultural Vocational School, Campus of Arslanbey, 41285, Karştepe - Kocaeli, Türkiye.
(3) Agriculture Province Directorate, Şanlıurfa, Türkiye.
(‘) Email: f_dokmen@hotmail.com & fun@kocaeli.edu.tr

Abstract:

The most important natural resource in arid areas, a large part of the rainfall is usually due to the loss of surface runoff and evaporation is undergoing. Collect rain water in order to ensure the sustainability of agricultural production, and this should be evaluated. Which is an old tradition in many countries of the world and water harvesting techniques used for thousands of years, have been developed in order to obtain drinking water and using/domestic water for the people.

Water harvesting systems in semi-arid areas, supporting of precipitation and therefore, to put in an order increasing efficiency able to supply enough water. Water harvesting is the best way to take advantage of a tool that allows rain water in the between agricultural activities. Water harvesting practices increases the amount of water per unit of cultivated area. Using of it to reduce impact of drought and surface flow use as useful. Damaged due to lack of preservation of soil and desertification and also reduced production potential in dryland areas, water harvesting help to reduce environmental damage, increasing vegetation cover and provide to protect of soil and water.

Runoff which is caused severe rainfall may be stored in the soil profile by water harvesting practices. Curved and flat land close to the surface, this surface runoff and occurs of sediment loss can be reduced. This study will focus on the importance of rainwater harvesting on soil and moisture conservation.

Keywords: Soil conservation, water conservation, water harvesting, water storage.
The Experimental Study of Influence of Biochar on Different Texture Soils Hydraulic Characteristic Parameters and Moisture Holding properties

Tian Dan¹, Qu Zhong-Yi¹*, Gou Mang-Mang¹ Li Bo¹, Lv Yi-Jia¹

¹College of Water Resources and Civil Engineering, Inner Mongolia Agricultural University, Hohhot, 010018, China
*(Corresponding author Email: quzhongyi68@sohu.com

Abstract:

In order to reveal the performance mechanism of biochar on saving water, high fertilizer use efficiency under different soil texture, based on the peanut shell biochar on sandy soil, silt loam hydraulic characteristic parameters and the characteristic of water is researched. The different biochar treatments (0, 0.05, 0.1, 0.15g·g⁻¹) of density, porosity, saturated hydraulic conductivity, saturated water capacity and soil water retention curve was determined using the cutting ring method, constant-head method and pressure membrane method. The results show that the application of biochar can change the sandy soil, silt loam structure. Sandy soil, silt loam bulk density decreased and sandy soil effective porosity increased with the increase of adding amount of biochar, and all treatments of silt loam total porosity from big to small in turn 0.15, 0, 0.05, 0.1 g·g⁻¹. Add peanut shell biochar inhibition of sandy soil water infiltration, increased soil water-holding capacity, and silt loam water-holding capacity in 0.15 g·g⁻¹ processing increase than control, in 0.1, 0.05 g·g⁻¹ processing reduced than control result. In the same water potential cases, along with the biochar content increased, sandy soil water-holding performance enhancements, and for silt loam hold water effect is not obvious. Therefore the peanut shell biochar on the impact of different texture soil hydraulic parameters is inconsistent, in which to improve the soil structure and moisture performance effect of sandy soil is remarkable. The result of the study for biochar in sandy soil amelioration and utilization water has very important applied and theoretical value.

Key words: Biochar; Soil porosity; saturated hydraulic conductivity; Soil water retention curve
Evaluation of Linear Anionic Polyacrylamide (LA-PAM) Application to Irrigation Canals for Seepage Reduction

Hamil Uribe(1,*), Rodrigo Figueroa(1), Luis Llanos(1)

(1) Agricultural Research Institute, INIA, Vicente Menzez 515 Chillan, Chile
(*)Corresponding author E-mail: huribe@inia.cl

Abstract:

Mediterranean climate of Chile determines a high use of water for agricultural production. Irrigation water is distributed through long channels which have high water loss difficult to control by conventional techniques. The objective of this work was to quantify water loss in channels and to evaluate the use of Linear Anionic Polyacrylamide (LA-PAM) to reduce seepage losses. The study was carried out in south-central area of Chile, in 300 km of channels whose flow varied between 0.12 and 25 m³ s⁻¹. Water users indicated channel sectors with potential leaks, which were selected for LA-PAM application. In 11 sectors of channels between 0.4 and 3 km in length, 1 to 3 LA-PAM applications were performed at rates of 10 kg ha⁻¹, considering wet perimeter area as basis of calculation. Thirty-one LA-PAM applications were performed over a 30.5 km length. Most of channels were large enough to allow motorboat moving against the current to carry-out LA-PAM application. In few cases, because channels were small, application was performed while walking. In both applications a seeder machine (Lhaura model 10502) was used to evenly distribute granulated polymer on water surface. Water flow was measured (StreamPro ADCP) at both ends of selected sectors, before and after LA-PAM application. Weekly measurements were made to quantify treatment effect duration. In each case water turbidity and temperature were measured (multi-parameter water quality checker Horiba U-50). Channels showed variable losses up 13%, and in one case 37%. Two channels showed 6% water gains. In more than 80% cases LA-PAM effect was positive, achieving loss reductions of 15 to 760 L s⁻¹. In other cases LA-PAM had a negative effect since it mainly affected water entry into the channel. It was determined that field conditions referred by users as indicators of leakage are not always correct and vary in time according to climatic conditions. Water loss was confirmed and it was possible to reduce seepage through LA-PAM applications provided that losses were known and correctly determined when applying the polymer. This could allow increasing irrigation security in critical periods, especially under drought conditions.

Keywords: canal seepage, irrigation, polyacrylamide
Role of plastic mulch on soil moisture availability for kiwifruit vines

M. Isabel Valín(1,2,*), Raquel Pontes (1), Carlos Marques (1), Celestina M. G. Pedras (2,3), Luis S. Pereira (2)

(1) ESA, Polytechnic School of Viana do Castelo, Refóios do Lima, 4990-706 Ponte de Lima, Portugal
(2) Biosystems Engineering Research Center, Tapada da Ajuda, 1349-017 Lisbon, Portugal
(3) University of Algarve, Campus Gambelas 8005-139 Faro, Portugal
(* isabelvalin@esa.ipvc.pt

Abstract:

Plastic mulch is used to control soil evaporation and increase the amount of soil water available for crops. Differently, an active ground cover, although having positive effects to prevent erosion and increase infiltration, competes with the crop for water and nutrients. Thus, the aim of this study was to monitor soil moisture content and assess the influence of plastic mulch along an irrigation season. The study was conducted in an orchard of Kiwifruits at Braga (41° 31’ N, 8° 27’ W, Portugal), between June 2011 and October 2011. The plot was irrigated daily through a drip irrigation system, in a 5 x 2.5 m spacing orchard, the emitters spacing was 0.5 m along the lateral, the flow discharge was 3.5 L.h⁻¹ per emitter and there were four laterals per crop row. From June to September irrigation was monitored by Frequency Domain Reflectometry (FDR - diviner 2000), with a frequency of three times a week. Four locations were observed, two with active ground cover, and two with a plastic cover under the vines. Each site is composed of five neutron access tubes, one in the crops row and four in track. For calibration of the equipment, 36 readings were made in the soil at 0.1 m depth intervals to the total depth of 0.6 m, together with samples of soil for the determination of gravimetric soil water content. The local calibration curve for each soil depth intervals presents better correlation coefficients (R²>0.90) than entire soil profile. The results show that the soil water content is kept higher where the plastic cover is used comparatively to the area with active ground cover.

Keywords: Plastic-film mulch, active ground cover, soil water content, Frequency Domain Reflectometry (FDR).
Improvement of plant growing techniques in drying up and water scarcity conditions

Georgi Mitev\(^{(1)}\), Jivko Demirev\(^{(1)}\), Krasimir Bratoev\(^{(1)}\)

\(^{(1)}\) “Angel Kanchev” University of Ruse, Bulgaria
\(^{*}\) Corresponding author Email: gmitev@uni-ruse.bg

Abstract:

Due to its specificity, seasonality and location of large areas, the crops are exposed to the greatest degree of risks posed by climate change. To maintain stability and increase yields is imperative to implement an innovative approach by which to optimize certain processes such as tillage, sowing and irrigation. The main tasks of innovative solutions are proposed to increase the soil water holding capacities in the root layer over a prolonged period of time, and improve the accuracy of the drilling process for row crops and vegetables by using biodegradable materials, and on this basis to optimize the irrigation by use of specialized software products to determine irrigation scheduling and irrigation requirements.

Keywords: plant, climate change, innovative technologies, soil water holding properties, accurate drilling with biodegradable materials, watering schedules and watering rates
Irrigation with magnetic water, a novel tool for improving crop productivity and water use efficiency

Mahmoud Hozayn (1*), Amany Abd El-Monem (2,3), Maha El-Shatter (2)

(1) National Research Centre, Field Crop Research Dept., Agric. & Biol. Div., El Behouth St., Dokki, Cairo, Egypt.
(2) National Research Centre, Botany Dept., Agric. & Biol. Div., El Behouth St., Dokki, Cairo, Egypt.
(3) Tabuk University, Branch Tyama, Faculty of Science, Biological Dept., Tabuk, KSA.
(*) Corresponding author E-mail: m_hozien4@yahoo.com

Abstract:

A great challenge for the agricultural sector is to produce more food from less water, particularly in arid and semi-arid regions which suffer from water scarcity. Utilization of magnetic water technology is considered as a promising technique to improve water use efficiency and crop productivity. Two field trials using wheat (Var. sakha-93), faba bean (var., nubaria-1), chick-pea (var. giza-3), lentil (var. Giza-9), canola (var. sero-6), flax (var. sakha-1) and sugar beet (var. baraka) were conducted at Research and Production Station, National Research Centre, Alemam Malek village, Al Nubaria district, Al Behaira Governorate, Egypt in 2009/10 and 2010/11 winter season to study and evaluate the effects of magnetizing irrigation water on growth, chemical constituent and yield and yield components of mentioned winter crops. The results showed significant positive effect of magnetic treatment on all studied parameters. The percent of increase in economic yield (ton ha-1) in response to magnetized water application reached to 13.71% at wheat, 8.25% at faba bean, 21.8% at chick pea, 29.53% at lentil, 36.02% at canola, 22.37% at flax and 19.05% at sugar beet crop as compared with normal water application. As well as water use efficiency was improved by 14.89, 7.25, 28.36, 30.00, 38.84, 22.64 and 12.06 for mentioned crops respectively.

Keywords: Magnetic water, winter crops, photosynthetic pigments, yield
Evaluation of effects of soil moisture content and wind condition on wind erosion in bare soil field

Kozue Yuge (1,*), Mitsumasa Anan (2), Yoshiyuki Shinogi (1)

(1) Faculty of Agriculture, Kyushu University, 6-10-1 Hakozaki Higashi-ku Fukuoka, Japan
(2) Takasaki Sogo Consultant, Co. Ltd., 3-7-5 Higashiaikawa, Kurume-Shi Fukuoka, Japan
(*) Corresponding author Email: yuge@bpes.kyushu-u.ac.jp

Abstract:

The objective of this study is evaluating the effect of the temporal changes of wind velocity and soil moisture condition on wind erosion in bare soil field to clarify the irrigation scheduling to prevent the wind erosion. The field observation and soil sampling were conducted in a bare field area located in Kagoshima prefecture, south-west Japan. The soil water retentivity and erodibility were evaluated by soil physical experiments. A simulation model describing air flow and transfer of soil particles was introduced to quantify the wind-blown soil considering the changes of wind velocity and soil moisture content. A wind tunnel experiment was conducted to verify the model accuracy. The experimental results indicated that the amount of soil loss by wind erosion increases when the wind velocity exceeds 6.0m/s, or the volumetric water content of soil surface decreases to 17%. Simulated wind-blown soil amount has good agreement with measured data.

Keywords: Lot-management water, Blown sand measurement, Simulation model, Wind tunnel experiment
Pest control and mitigation of the heat stress with kaolin may also lead to save water in Mediterranean environments

Francesca Boari\(^{(1)}\), Mladen Todorovic\(^{(2)}\), Antonio Donadio\(^{(1)}\), Maria Immacolata Schiattone\(^{(2)}\), Vito Cantore\(^{(1)}\)

\(^{(1)}\) Institute of Sciences of Food Production, CNR, Via Amendola, 122/O, 70125 Bari, Italy
\(^{(2)}\) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
\(^{(\ast)}\) Corresponding author E-mail: francesca.boari@ispa.cnr.it

Abstract:

Kaolin-based particle film technology (Pft) employs a multi-functional, environmentally friendly material that provides effective insect control, mitigates heat stress, and contributes to production of high-quality fruit and vegetables. These characteristics make kaolin suitable also for organic farming, especially in arid and semi-arid environments.

The presence of mineral particles on leaves and fruit surfaces interferes with physiological processes, mainly with heat and radiation balance and gas exchange. Several experimental findings show that the Pft, as well to limit the damage from some insects, changes the radiative and thermal regime of the different organs of the plant that may result in a significant reduction in stress from high temperatures, mainly sunburn, as widely proven on apple, pear, pomegranate and tomato.

The Institute of Sciences of Food Production, CNR, for several years is carrying out research to test the effects of kaolin on the control of the heat stress and some insects of fruit trees and vegetables. In addition, is evaluating the effects on gas exchange, water and salt stress. In the latter area, was assessed the gas exchange, evapotranspiration and water use efficiency (WUE) of tomato, orange and bean. In addition, we studied the effects on transplanting stress of seedling of tomato, pepper, eggplant and zucchini. In this paper we report some significant results that highlight the positive effect of kaolin on the reduction of evapotranspiration, water use, water and saline stress, and improvement of WUE.

The water and salinity stress has caused the reduction of the leaf water potential, stomatal conductance, leaf net photosynthesis and transpiration and the increase of leaf and canopy temperature of tomato plants. The kaolin has resulted in an improvement of the water status of the plant, the reduction in stomatal conductance, net photosynthesis and transpiration under well watered or low salinity conditions. Instead, under drought or salt stress, the kaolin was effective to limiting the reductions in net photosynthesis and to reduce leaf and canopy temperature, resulting respectively in a 15 and 20% in WUE increase. The leaf and canopy temperature was slightly affected by kaolin, in different ways in different water/salt stress treatments. In particular, while in non stressed plant it was 0.2-0.8 °C higher in the kaolin-treated plants, the situation was reversed in stressed plants. In fact, in the latter situation, the kaolin has determined 0.2-1.5 °C reduction in canopy temperature, especially at noon time. The variations of the canopy temperature show that the kaolin influences the
thermal balance of vegetation mainly for the dual effect of reflection of the incoming radiation and partial occlusion of the stomata.

Kaolin has reduced by 13% the crop evapotranspiration of bean and has resulted in a 6% increase in the yield-WUE. In well watered orange tree kaolin led to a reduction of 16% in transpiration rate and 11% increase in WUE. Kaolin has proved effective in limiting transplant stress. Indeed, during the rooting of seedlings, resulted in an increased accumulation of dry biomass and height of seedlings of 17 and 39% respectively.

The results are in agreement with other works reporting a reduction of stomatal conductance and, consequently, evapotranspiration. The reduction in stomatal conductance and water loss indicates that kaolin can be efficiently utilized as an antitranspirant to alleviate effects of drought and salinity and to save water in dry regions.

**Keywords:** kaolin, particle film technology, tomato, bean, orange, evapotranspiration, water use, water stress, salt stress
Smallholders Minimum Tillage Planter Adoption in Bangladesh: A successful case of private sector involvement for technology commercialization

M. Enamul Haque(1,*), Sania Rahman Nabila(2), Richard W. Bell(3)

(1) International Development Enterprise, House 21, Road 123, Gulshan 1, Dhaka, Bangladesh
(2) Green Machinery Store, 90/90 A Nawabpur Road, Dhaka, Bangladesh
(3) Murdoch University, Australia
(*)Corresponding author E-mail: enamul.haque@ide-bangladesh.org

Abstract:

Bangladesh is the leading country of smallholders’ 2-wheel tractor based farm mechanization. The main power sources for land preparation are mainly comes from about 500,000 Chinese made 12 to 16 hp two-wheel tractors (2WT). Additional two millions of Chinese 4 to 16 hp diesel engines which are used to power varied activities including rural road and water transportation of agricultural commodities. Small agricultural machinery is being widely used for irrigation, threshing, shelling, winnowing, and rice de-husking. The use of two wheel tractors for land preparation and rural transportation have increased rapidly in the country since the government of Bangladesh has withheld the standardization policy for importation and opened the market of 2WT after the devastating flood of 1988. Many private companies have started to import and commercialize the 2WT and other implements since late 80s. The 2WT becoming popular due to versatile use, lower cost for tillage, easy to operation, repair and maintenance; availability of spare parts and mechanics, lesser time required for cultivation. Initial developments of minimum tillage planter using 2WT in Bangladesh were started in 1995 with the importation of the Chinese-made 2BG-6A seed drills. This seed drill accomplished three operations -shallow but fine tillage, placement of seed in furrows and levelling in single pass operation. Many attempts were taken including project led procurement and selling to farmers; involving research, extension, local manufacturers, and non-government organizations to popularizing and selling the minimum tillage planters that can even reduce production cost by 30 %, increase crop yield by 15 - 18 %. The adoption of minimum tillage planters have started in 2003 with different form of uses for fine tilth onion and garlic land preparation with 11 units of 2BG-6A while a private company was involved for commercialization process. Until end of 2012 there are more than 3,200 minimum tillage planters have been imported and locally fabricated that enhanced the commercialization process of minimum tillage planter in Bangladesh as mostly using for single pass shallow tillage (SPST). Since 2003, the total area coverage of SPST was 164,000 ha, saved 787,000 l of diesel fuel, reduced irrigation water use by 24 %; reduced production cost by 30 %, and reduced about 2000 t of CO₂ emission to atmosphere. The adoption of 2BG-6A planter would an option for introduction of conservation agriculture in Bangladesh. In this paper we will describe the multi-stakeholders approach for technology adoption, dissemination, and commercialization process of the minimum tillage planter.
Keywords: single pass shallow tillage, two wheel tractor, onion and garlic, land preparation cost
Session 3
Sustainability of groundwater exploitation for agriculture
GeSAP: a management tool to evaluate the acceptability of irrigation constraint measures for groundwater protection

Ciro Apollonio(1,*) , Ivan Portoghese(2), Daniela D’Agostino(3), Raffaele Giordano(2), Stefania Ingravalle(1), Nicola Lamaddalena(3), Alberto F. Piccinni(1), Alessandra Scardigno(3), Michele Vurro(2)

(1) Politecnico di Bari, DICATECH, via Orabona 1, 70124 Bari, Italy
(2) Consiglio Nazionale delle Ricerche, IRSA – UOS di Bari, viale F. De Blasio 5, 70132 Bari, Italy
(3) CIHEAM, IAM-Bari, via Ceglie 9, 70010 Valenzano (BA), Italy
(*)Corresponding author E-mail: ciro.apollonio@libero.it

Abstract:

Water resources management is often characterized by conflicts in many arid and semi-arid regions, where agriculture is the main user of groundwater (GW), causing problems with the quantity and quality of water, but there are few institutional policies and regulations governing sustainable GW use. In this work, the authors suggest an integrated modelling tool for enabling local GW management, capable of combining the need for GW protection with socio-economic and behavioural determinants of GW use. In the proposed tool, the integration is reinforced by the inclusion of multiple stakeholders and the use of Bayesian Belief Networks (BBNs) to simulate and explore their attitude to GW exploitation and their responses to the introduction of new protection policies. Technically speaking, GeSAP integrates the features of the BBNs and the hydrological system properties in a GIS-based decision support system which can elaborate and analyse scenarios concerning the pressure on GW due to exploitation for irrigation, and the effectiveness of protection policies, taking into account the level of consensus. In addition, the GIS interface makes it possible to spatialize the information and to investigate model results. The adopted approach has been discussed with a relevant number of experts in GW management policies and irrigation management, and its main strengths and weaknesses have been identified. Increasing awareness of the existence of potential conflicts and the need to deal with them can be seen as an appropriate approach in regions where Sustainable Water Management is still seen as a purely technical issue. The Apulia region of southern Italy was adopted as a representative study area for the development and test of the GeSAP tool due to the limited availability of surface water resources and widespread GW overexploitation. The GeSAP tool allowed to quantitatively assess the conflict degree in the study area caused by the introduction of new policies for the reduction of GW for irrigation purposes. The less acceptable the policy is, the more likely it is that conflicts will arise between farmers and the Regional Authority. Moreover, the experimental application of the GeSAP tool was addressed to investigate the impacts of different crop scenarios in supporting GW planning and management in the Apulia region as a trade-off between the water cost and crop values. Results showed that GeSAP can simulate farmers’ behaviors concerning the selection of water sources for irrigation, allowing the
evaluation of the effectiveness of a wide range of strategies which impact water demand and consumption. The tool can be applied to different regional areas, as it can be flexibly adapted to take into account any GW system with its unique situation regarding the nature of the water issues involved, including the social, economic, and legal constraints.

**Keywords:** Bayesian Belief Networks, Groundwater protection policy, Stakeholder involvement, Conflict mitigation
Comparative study for Estimating Ground-Water Recharge from Hydrograph Analysis and Groundwater Fluctuations in Semiarid to dry subhumid Region - Case Study of Al-Khazir Gomal Basin North of Iraq

Jassas\(^{(1,*)}\), Merkel\(^{(2)}\)

\(^{(1)}\) Hydrogeological Institute, Gustav-Zeuner-Str. 12, 09599 Freiberg, Germany
\(^{(2)}\) Hydrogeological Institute, Gustav-Zeuner-Str. 12, 09599 Freiberg, Germany
\((*)\)Corresponding author Email: husseinjassas@yahoo.com

Abstract:

The mean annual recharge of Al-Khazir Gomal Basin was estimated using two approaches, hydrograph analysis and water table fluctuation (WTF). The long-term mean daily streamflow records of Al-Khazir River were used to estimate groundwater discharge (net recharge) by baseflow hydrograph separation and displacement recession curve methods. Four baseflow separation methods were used in this work, namely one manual separation (constant slope methods) and three automated separation methods. The automated separation methods are included into the Web based Hydrograph Analysis Tool (WHAT). Stable base flow analysis were also applied in all the four methods to avoid overestimation in base flow records resulted from rainstorm events. Finally, base flow index (BFI) was calculated to baseflow record and stable baseflow. Estimating recharge in the two aforementioned methods (hydrograph analysis and water table fluctuation) is useful, but the different approaches used in these two methods have to be considered when comparing the results. Estimating recharge by water table fluctuation method does not incorporate spatial variability contained in the whole watershed. However, hydrograph analysis method can give a comprehensive estimation of net recharge for the entire watershed, which include different recharge mechanisms. The recharge estimated by WTF was more reasonable (17 % of the rainfall) than the recharge estimated by stable baseflow separation (20% of the rainfall). In general, the results are acceptable, if we take into account the high permeability of the aquifer which consists mainly of gravel and sand, and the presence of two recharge mechanism (diffusive recharge and focus recharge from the river bed). The displacement recession curve method is not suitable for large watershed area, and the recharge estimated by this method showed an overestimation (24% of the rainfall).

**Keywords:** Regional groundwater recharge, Hydrograph analysis, Water table fluctuation.
The sustainability of groundwater exploitation for agriculture in the case of a wide coastal karstic aquifer (Salento, Southern Italy)

Andrea Romanazzi(1,*), Francesco Gentile(1), Giuliana Trisorio Liuzzi(1), Maurizio Polemio(2)

(1) University of Bari “A. Moro” - DISAAT, Bari, Italy
(2) CNR-IRPI, Bari, Italy
(*)Corresponding author E-mail: romanazziaandrea@gmail.com

Abstract:

This note aims to define the sustainability of groundwater exploitation for agriculture in the case of a wide coastal karstic aquifer. Numerical modelling was used as a tool to point out the criteria to reduce the quantitative and qualitative groundwater degradation risks. The real heterogeneous aquifer has been simulated as an equivalent homogeneous porous media within cells or elements. Its surface extension is 2230 km² and it was uniformly discretized into 97,200 cells, each one with an area of 0.6 km².

Vertically, to allow a good lithological and hydrogeological discretization, the area was divided into 12 layers, from 214 to -350 m asl. Inactive cells were used along the boundary with the confining Murgia-Salento aquifer, as conceptual underground watershed due to the absence of flow. A CHD (Constant Head Boundary) was used along the sea boundary, while additional boundary conditions were used for salinity modelling. The results of calibration can be summarised considering the correlation coefficient, equal to 0.92, the standard deviation, equal to 0.7, the mean square error, equal to 0.65 and the absolute mean residue (RMS), equal to 12%. The water budget of the study area was calculated in each cell using a GIS elaboration. Rainfall and temperature monthly data coming from 16 gauges were considered since 1915 until 2000, considering an infiltration coefficient (IC) for each hydrogeological complex. The period 1925-1975 was selected to assess the water balance for the steady state conditions, thus avoiding the trend effect of climate change, particularly relevant in the area starting from the eighties. After implementing and calibrating the steady-state scenario two transient validate-scenarios were implemented for two decades: eighties and nineties. In these decades the discharge increase for drinking and irrigation purposes and the recharge decrease due to climate variations were considered.

The salinity and piezometric trends were thus obtained. As most of the global climate change models predict decreasing precipitation and increasing temperatures and hence evapotranspiration in the Mediterranean region, three forecasts piezometric scenarios, 2000-2020, 2020-2040 and 2020-2060 were subsequently implemented. On this basis, the quantity degradation of groundwater resources was assessed, showing a non-sustainability of the current trend of groundwater exploitation.

Key-words: groundwater modelling, groundwater management, coastal karstic aquifer, Climate change, quantity groundwater degradation
Investigation of the relationship between groundwater level fluctuation and vegetation cover by using NDVI for Shaqlawa basin of Kurdistan region, Northern Iraq

Seeyan\(^{(1,*)}\), Merkel\(^{(1)}\), Abo\(^{(1)}\)

\(^{(1)}\) Hydrogeology Institute, Gustav-Zeuner-Str. 12, 09599 Freiberg, Germany
\(^(*)\) Corresponding author Email: shwanom2003@yahoo.com

Abstract:

Groundwater as an important component of hydrological cycle and it is the main water resource for fresh water and irrigation, particularly in arid and semi-arid area. Groundwater availability is one of the controls on vegetation distribution in semi-arid area; this distribution has been observed in the Shaqlawa Basin located in Kurdistan Region, Northern Iraq. The objective of this study was to assess how the vegetation affect shallow groundwater table based on the relationship between the normalize difference vegetation index (NDVI) and measured groundwater table. The NDVI derived from TM 4-5 image satellite data, we use the NDVI data for years 2006, 2007, 2009 and 2010, with the groundwater depth measurement for 11 monitoring wells for this study. Statistical analysis was performed and P-value show statistically significant relationship between the groundwater depth and NDVI area at the 95 confidence level for all years investigated. The NDVI values at different depth to water table (DWT) intervals indicate that higher vegetation coverage and more plant diversity exist at places of shallow groundwater. The NDVI values decrease with increase of groundwater depth and the statistic analysis shows that the groundwater depth has negative relationship with NDVI.

Keyword: Groundwater Depth, NDVI, Remote Sensing, Semi-arid area
Irrigation Delivery Performance Versus Environmental Externalities: A Risk Assessment and Management Perspective

Daniele Zaccaria\textsuperscript{(1,\textdagger)}, Giuseppe Passarella\textsuperscript{(2)}, Daniela Dagostino\textsuperscript{(1)}, Raffaele Giordano\textsuperscript{(2)}

\textsuperscript{(1)} Mediterranean Agronomic Institute of Bari (CIHEAM-IAMB,) Via Ceglie 9, Valenzano, Bari, Italy
\textsuperscript{(2)} Istituto di Ricerca sulle Acque (IRSA), Consiglio Nazionale delle Ricerche (CNR), Via De Blasio, 5 – 70125 Bari - Italy
\textdagger\textit{Corresponding author E-mail: d.zaccaria68@gmail.com}

Abstract:

This paper presents results from a research and modelling work conducted on an irrigated agricultural area of southern Italy that aimed at mapping, assessing and managing the environmental risks of soil and aquifer degradation most likely resulting from poor irrigation delivery performance. The area is serviced by a gravity-fed piped irrigation delivery system managed by a local Water Users Organization, and is intensively cropped by small land-holders with high-value market-oriented horticulture. The investigations revealed significant aquifer salinity increase from winter to summer months that were referred to concentrations of groundwater pumping by farmers during peak irrigation demand periods, although irrigation delivery of surface water is usually available to growers from the distribution network throughout the entire crop irrigation season. Phenomena of seawater intrusion were documented by several research campaigns conducted on the study area in the last decades, as resulting from mining of the coastal aquifer mainly for agricultural and touristic purposes. The environmental hazards to the aquifer and agricultural soils were appraised through the use of a simplified Risk Assessment procedure that allowed identifying the risk-generating processes and assessing the overall risks significance. The risk assessment procedure was supported by considering the stakeholders’ perspective through the development and use of Fuzzy Cognitive Maps (FCMs) to simulate the groundwater exploitation attitude of farmers versus water withdrawals from the collective distribution network. FCMs proved to be a useful tool to support public participation and to represent the knowledge domain of the stakeholders in the decision making process of water resources access, use and management.

Viable risk management options were simulated and appraised on the basis of different criteria that also entailed the use of dynamic analysis of FCMs to explore and to understand the reaction of the system in response to different changes. Finally, some viable mitigations to the foreseen environmental risks were envisaged to comply with possible future agricultural and territorial policies aiming at more sustainable use of land and water resources in the area.

Keywords: Irrigation delivery systems, Soil and Aquifer Degradation, Seawater intrusion, Environmental Risk Assessment & Management, Fuzzy Cognitive Maps.
Groundwater Recharge in Titas Upazila in Bangladesh

Kanoua\(^{(1,*)}\), Merkel\(^{(2)}\)

\(^{(1)}\) Hydrogeological Institute, Gustav-Zeuner-Str. 12, 09599 Freiberg, Germany
\(^{(2)}\) Hydrogeological Institute, Gustav-Zeuner-Str. 12, 09599 Freiberg, Germany
\(^{(*)}\)Corresponding author Email: wael_kanoua@yahoo.com

Abstract:

An adequate representation of the recharge component is essential to any groundwater model. In this work we used water balance and water table fluctuation methods to calculate groundwater recharge in a particular area to be used later as an input for a groundwater model. Study area (107 Km\(^{2}\)) is located in Titas Upazila/Comilla district in Bangladesh, whose climate is classified, using the Köppen Climate Classification, as tropical with distinct dry season. Our calculations are done season-wise as long-term monthly average for both monsoon season and non-monsoon season separately. Priestley Tailor method, Blaney–Criddle method, and adjusted pan method were adapted to calculate the actual evapotranspiration in the wet season. Alternatively, in dry months, when irrigation is active and the matter is much complex, different method are used and tested to estimate the actual evapotranspiration (AET). Deficit and surplus are also calculated with the help of soil moisture data. Neither measured soil moisture data are available for our study area nor does satellite data give accurate estimation, so soil moisture was driven from a linear regression analysis between measured data in different parts of Bangladesh and NOAA soil moisture data. Precipitation during dry months has no contribution to the annual recharge; that lets us draw a conclusion, based on our calculations, that for best estimation of recharge, more attention should be given to rainfall during the wet months. The recharge output of the water balance method is compared with recharge calculation using water table fluctuation method and with estimations from previous studies on a national scale in Bangladesh.

Keywords: groundwater recharge, evapotranspiration, Titas Upazila, Köppen Climate Classification, monsoon
The KNOW project (implementing the Knowledge of NitrOgen in groundWater) implementation in a NVZ Sardinian area

Daniele Pittalis\(^{(1,*)}\), Giorgio Ghiglieri\(^{(1,3)}\), Riccardo Biddau\(^{(3)}\), Cristina Buttau\(^{(3)}\), Alberto Carletti\(^{(1)}\), Clara Demurtas\(^{(1,2)}\), Luca Doro\(^{(1,2)}\), Maria Teresa Melis\(^{(3)}\), Maria Antonia Pulina\(^{(2)}\), Giovanna Seddaiu\(^{(1,2)}\), Pier Paolo Roggero\(^{(1,2)}\), Rosa Cidu\(^{(3)}\)

\(^{(1)}\) NRD- Nucleo Ricerca Desertificazione, Università degli Studi di Sassari, Viale Italia 39, IT
\(^{(2)}\) Dip. di Agraria, Università degli Studi di Sassari, Viale Italia 39, IT
\(^{(3)}\) Dip. Scienze Chimiche e Geologiche (DSCG-UNICA) – Università degli Studi di Cagliari
\(^{(*)}\) Corresponding Author Email: dpittalis@uniss.it

Abstract:

In EU, nitrate pollution of groundwater is particularly relevant. Through the Nitrate Directive (ND, 91/676/EEC), the EU countries identified Nitrate Vulnerable Zones (NVZ’s), developed protocols of good agricultural practices and set up action programs for the management of farm wastes. However, the ND is emblematic of the asymmetries between the objectives and the effectiveness of its implementation, and the nitrate pollution of EU groundwater has not decreased following over 20 years of ND implementation.

The KNOW project\(^1\), coordinated by University of Cagliari (Sardinia, Italy) in partnership with NRD (University of Sassari), is framed within research activities of the joint research team for the integrated risk assessment of aquifer pollution of agricultural origin (www.agroscenari.it; www.wadismar.eu; www.uniss.it/nrd). A NVZ was identified in the dairy farming district of Arborea (W-Sardinia). Previous research had shown that nitrate pollution of groundwater in Arborea can have different sources, including chemical and organic fertilizers and urban sewage. This problem is particularly severe in relation to the multi-layer aquifer hosted in the Quaternary sands, that represents one of the most relevant source of freshwater in the study area. Due to its typology, the aquifer is highly vulnerable to pollution.

In this framework, KNOW aims to develop integrated knowledge on nitrate flow in groundwater, by means of:

a) evaluating the efficiency and effectiveness of geochemical and isotopic tracers ($^{18}$O, $^2$H, $^{15}$N, $^{34}$S and $^{11}$B) as indicators of the groundwater recharge areas and nitrate pollution sources in the Arborea NVZ;

b) define, by means of mathematical models, the relationship between agricultural practices and the water quality that contributes to recharge the aquifers;

c) propose innovative protocols for detection, monitoring and processing of qualitative and quantitative parameters of groundwater resources.

The KNOW project is integrating approaches from geochemistry, hydrogeology and agronomy.

The research is focused in a transect of 2 x 0.2 km where the groundwater flows and spatial distribution of the nitrate concentration have been assessed in the sandy aquifer through quarterly monitoring conducted in 2007-2009 on 34 wells. Along the transect,
farmers were interviewed about the agronomic management practiced in each field in the last 5-years and a bi-monthly sampling of groundwater from 12 wells was made for the chemical and isotopic data determination. The field water balance was assessed with the EPIC model.

The actual mean nitrate concentration in the wells was 126 mg L\(^{-1}\); the weighted mean N surplus of the area is 320 kg ha\(^{-1}\) and the mean water surplus 256 mm. If all the N surplus was leached by the percolation water as nitrate, the nitrate concentration would range from a min of 380 to over 650 mg L\(^{-1}\), some five times higher than the actual concentration. The hypotheses being explored to understand the apparent discrepancy include the dilution effect from the upstream groundwater and the self-depuration processes of the aquifer through denitrification. The research activities involve the local farmers’ cooperative (some 200 farmers breeding 35,000 dairy cows) not just as data suppliers but as pro-active stakeholders in addressing the pollution of their own water.

\(^{1}\) funded by Autonomous Region of Sardinia (2012-14) in the frame of the Regional Law 7/2007: “Promotion of scientific and technological innovation in Sardinia”.

**Keywords:** Nitrate Pollution, Groundwater, Best Agriculture Practice, Arborea (Sardinia)
Groundwater dynamics at irrigated field scale: Case study from Lower-Mondego Irrigation District, Portugal

Manuel Nunes\(^{(1,2)}\), José Manuel Gonçalves\(^{(1,2)}\), João L. M. P. de Lima\(^{(3)}\), Luis Santos Pereira\(^{(1)}\)

\(^{(1)}\) CEER - Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Lisbon, Portugal
\(^{(2)}\) Coimbra Higher School of Agriculture, Coimbra, Portugal.
\(^{(3)}\) Department of Civil Engineering, Faculty of Science and Technology, University of Coimbra, Coimbra, Portugal.

(*)Corresponding author E-mail: jmng@esac.pt

Abstract:

Lower-Mondego Irrigation District is located in the centre west of mainland Portugal, with a total irrigated area around 12600 ha. Surface irrigated maize and paddy rice are the main crops. The groundwater table is generally shallow, depending upon the behavior of the regional alluvial aquifer, irrigation management and drainage functioning, thus upon the control of water levels and discharges in drainage ditches. Groundwater table rises throughout the crop season, mainly due to paddies, and decreases in late summer, after draining the rice paddies. The shallow groundwater table impacts crop production both through capillary rise and reducing the vadose zone depth.

Due to the complexity of interactions among soil water, groundwater, drainage systems and irrigation, the objectives of research consist of better understanding the groundwater dynamics and its relationships with soil water, irrigation and crop management aiming at improving overall management at farm and project scales. The HYDRUS model is used to simulate the water fluxes in the vadose zone of maize irrigated fields, being calibrated on field observations of soil water and the groundwater table dynamics, thus evaluating the drainage and capillary rise fluxes in/to the root zone. A good assessment of the capillary fluxes is particularly important to support farmers in controlling the application of excessive water depths and the consequent environmental impacts and non-beneficial water use. The MODFLOW model (2000 version for three-dimension simulation) is used to assess the behavior of the groundwater table level in relation to recharge from irrigation percolation flows, seepage from the drainage ditches and interactions with the surrounding aquifer system. The approach adopted considers combining these two models in an iterative and interactive procedure, simulating the water table level and the water dynamics at field scale.

The monitored fields are two land parcels with sandy-loam and silty-loamy soil textures. Observations performed there were used for models parametrization and calibration. The soil water properties required for HYDRUS are described by the van Genuchten equations. The groundwater table level is observed with piezometric tubes and the soil moisture with calibrated TDR probes. Observations include field irrigation and crop development parameters. To support using MODFLOW, information includes the
aquifer-system geometry, hydraulic conductivity, and specific storage, as well as groundwater heads and ditches levels observed in specific points around the observation fields. The MODFLOW recharge package allowed evaluating the response of the groundwater table. The recharge consists in vertical flows from the unsaturated zone simulated by HYDRUS model, while lateral recharges are due to seepage from ditches that surround the parcel and the adjacent rice paddies. The drainage package simulates the flow into the drainage ditches and deep percolation.

This paper presents results of field trials and simulations: (1) Models parameterization for two different soil textures; (2) A comparison between simulated and measured groundwater table depths, according to the dynamics of capillary rise and drainage in/out of the vadose root zone, obtained by combining both models.

**Keywords**: irrigation and drainage management; groundwater modelling; capillary rise; vadose zone; Lower-Mondago Irrigation District.
Possibility of geothermal exploitation in south Algeria for agriculture

Ouali Salima (1,*), Bouzidi Khedidja (1), Abdeladim Kamel (1)

(1) Centre de Développement des Energies Renouvelables (CDER), Renouvelable, B.P. 62 Route de l'Observatoire, 16340, Algiers, Algeria
(*)Corresponding author E-mail: ouali.salima2000@gmail.com

Abstract:

The South of Algeria contains two important geothermal reservoirs in depth at geological formations of the Intercalary Continental (IC) called the Albian and the Terminal Complex (CT). These two aquifers that constitute the North Western Sahara Aquifer System (NWSAS) are considered as the largest water reserves in the world and cover an area of over 1 million Km².

In this article we present an overview of the North Western Sahara Aquifer system and describe the main possibilities of its utilization in the agriculture.

Keywords: geothermal reservoir, Intercalary Continental, Terminal Complex, Albian, agriculture
Session 4
Decision support systems and modelling tools
Hydro-Tech, an integrated decision support system for sustainable irrigation management: (I) main algorithms and field testing

Mladen Todorovic(1,*), Vito Cantore(2), Erminio E. Riezzo(3), Mario Zippitelli(3), Angelo Gagliano(4), Vito Buono(1)

(1) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
(2) CNR – Institute of Science of Food Production, Via Amendola 122/O, 70126 Bari, Italy
(3) Sysman Progetti & Servizi srl, Via A. Montagna 2 - zona PIP, 72023 Mesagne (BR), Italy
(4) Dyrecta Lab, Via Vescovo Simplicio 45, 70014 Conversano (BA), Italy
(*)Corresponding author E-mail: mladen@iamb.it

Abstract:

In the framework of a specific project supported by the EC-ERDF programme in the Apulia Region (Italy), a local consortium of private ICT companies and Research institutions is currently developing and testing a Decision Support System called ‘HydroTech’ (HT-DSS), which aims to integrate the latest scientific knowledge on crop water requirements and irrigation scheduling with the more advanced technological solutions for the continuous sensor-based monitoring in the soil-plant-atmosphere system, as well as the remote and automated control of irrigation supply networks. The ‘core’ algorithm of HydroTech-DSS is based on the well-established FAO-56 methodology (Allen et al., 1998), further improved in order to allow the application of different models for ETo estimation, to apply the heat unit concept for the simulation of crop development, to customize irrigation strategies options according to a complete set of priorities (including deficit irrigation), and finally to allow the further improvement of the Kc curve according to crop/variety specific biometric and phenological measurements. An additional ‘multi-plot/crop management module’ has been created for the real-time simulation of the crop water balance, as well as to simulate a 3 to 7-days projected scenario using the high-resolution weather forecasting data, in order to forward a day-by-day irrigation planning. Then, a ‘dynamic optimizer’ supports the optimal setting of the irrigation priorities at the farm scale by taking into account water availability at the source (e.g. well, reservoir), the level of water stress reached by each crop type and the economic parameters including the cost of applied management practices and expected market price. At plot scale, the continuous monitoring of soil water status by capacitance soil water sensors enables the HT-DSS to further support the application of ‘closed-loop’ irrigation control strategies by setting irrigation timing and amount in order to reach a specific soil moisture content and/or to avoid/control plant water stress. Finally, HT-DSS integrates a set of flexible solutions for partially or completely automated irrigation management, by means of real-time and remote monitoring in the water supply network (volumes, discharges, pressures, etc.) and control of actuators (at the level of pumping station, hydrants, electro-valves, etc.) to support farm operational management, as described in the companion paper (Riezzo et al., 2013; this issue). The preliminary results of the DSS implementation are presented in relation to the on-going experimental and demonstration activities established in
different local farms, and an example of application for a peach orchard is briefly introduced.

**Key words:** irrigation, decision support system, water balance model, capacitance sensor, optimization.
Hydro-Tech, an integrated decision support system for sustainable irrigation management: (II) software and hardware architecture

Erminio E. Riezzo\(^{(1, *)}\), Mario Zippitelli\(^{(1)}\), Donato Impedovo\(^{(2)}\), Mladen Todorovic\(^{(3)}\), Vito Cantore\(^{(4)}\), Vito Buono\(^{(3)}\)

\(^{(1)}\) Sysman Progetti & Servizi srl, Via A. Montagna 2 - zona PIP, 72023 Mesagne (BR), Italy  
\(^{(2)}\) Dyrecta Lab, Via Vescovo Simplicio 45, 70014 Conversano (BA), Italy  
\(^{(3)}\) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy  
\(^{(4)}\) CNR – Institute of Science of Food Production, Via Amendola 122/O, 70126 Bari, Italy  
\(^{*}\)Corresponding author E-mail: riezzo@sys-man.it

Abstract:

In the framework of the HydroTech project (supported by Apulia region and the EC-ERDF programme), local private ICT companies in collaboration with research institutions are developing and testing at farm scale an integrated Decision Support System (DSS) for irrigation management, through the integration of advanced software and hardware technologies. Hydrotech-DSS provides standard interfaces, which connect on-field devices with client software application through a Data Cloud Network (Hydrotech Data Cloud, HDC). The HDC is composed of: 1) Knowledge Data Base, a DB for large amount of data coming from heterogeneous but strongly correlated sources; 2) a ‘gateway’ based on web services technology, to connect external (on-field) devices together with an open standard communication protocol; 3) a set of software components constituting the APP Data Chain from source to destination passing by elaboration steps (Data Assimilation, Model Engine, Decision Maker). The Decision Maker module supports two types of decision system: the MSS (Management Support System) enables the end-user to manage the work flow of his farm, whereas the DSS (Decision Support System) supports him during irrigation/fertigation management activities (e.g. timing and amount of irrigation according to weather forecast, crop water stress, irrigation system constraints, etc.). The system allows fast and simply information transfer directly to the field through an easy interface accessible with new smart devices (tablet, smartphone, etc.). The user interface allows: 1) to receive aid for the decision (irrigation and fert-irrigation advice) directly on the field within its validity time window by means of “push-pull” technology; 2) to interact with the HDC to send the feedback (e.g. treatment registration), characterize the individual farm and adjust the system parameters; 3) to use different type of software client application, such as classic client-server for professional use on rugged tablet and computers, or smart/user friendly for mobile device and web based; 4) to work off-line and to synchronize the database when data connection will be available; 5) to enable users for the automation and remote control of irrigation system equipment (e.g. hydrants, electric valves). With respect to the design and development of the hardware infrastructure, the ‘field unit’ is composed by sensor devices (EAP, end-acquisition-point), actuator devices and the so-called ‘coordinator’ which is aware of the whole configuration and logics to be respected. Each sensor/actuator must be placed in the
most favourable site, and each EAP is equipped with Li-lon rechargeable battery and a solar panel in order to have the highest installation facility. Acquired data can be transferred to the ‘coordinator’ by means of different technologies (LAN, 3G, GPRS, ZigBee, WiFi, Bluetooth, etc.). The coordinator is a gateway provided with moderate computation and storage capabilities able to collect data from the EAP, perform basic checks and transmit them to the centralized cloud system, which is able to perform the main computations. Many different technologies can be adopted to transfer data to the cloud system. Once the irrigation decisions have been computed and approved, commands are sent to the ‘coordinator’ which is responsible to forward these commands to actuators adopting specific field strategies.

**Key words:** irrigation, decision support system, water management, wireless communication, automated control.
Tools to support water management in agriculture under policy and climate change. The Trebbia irrigation district experience

Guido M. Bazzani(1,*), Roberto Genovesi (2), Paolo Mannini (2)

(1) Consiglio Nazionale delle Ricerche, IBIMET, Via Piero Gobetti, 101 Bologna, Italy
(2) Consorzio Canale Emiliano Romagnolo - CER, V. Masi 8, 40137 Bologna, Italy
(*)Corresponding author E-mail: g.bazzani@ibimet.cnr.it

Abstract:

The use of models and tools is recommended in the Water Framework Directive to support the implementation process of the Directive which should guarantee the “good status” of nearly all European waters by the year 2015. Agriculture has been identified as a strategic sector and environmental objectives are progressively integrated into the reformed agricultural policy but the achievement of this ambitious goal is made more difficult by climate change which is recognized to have a strong impact on freshwater resources. The paper describes the Trebbia irrigation district experience in the Po valley, where different tools support the Irrigation Board in preparing the water conservation plan, in accordance with WFD requirements and Water Blueprint recommendations as implemented in Emilia-Romagna Region. A multilevel approach in modelling is adopted. At a higher level, conceptual models support the definition of a common conceptual framework for cross-disciplinary work involving water managers, stakeholders and scientists. The information produced, clarifying the areas of greatest uncertainty and influence on system evolution under different assumptions, help prioritise further fields of investigation. At lower levels, quantitative models support specific analyses exploring the strength of interactions and the sensitivity of the system to changes. Different tools are adopted and adapted to respond to the specific nature of the district. A first instrument can be visualized as a DS designed to support the Irrigation Board in water planning and management at the basin scale considering climate and policy changes under different economic conditions by scenario analysis. A second tool considers the farm scale using bio-economic models integrating agronomic, hydraulic, economic and environmental data and assesses the impact of agri-environmental measures and environmental regulation. IRRINET, a tool developed by the CER to support irrigation at farm level in Emilia Romagna is used to quantify water requirements. Results show that water reallocation among sub-basins and a different scheduling can have positive environmental effects lowering the pressure on the aquifer but existing farmers’ rights on water limit its implementation. The modelling exercise favoured the identification of accompanying measures necessary to implement balanced solutions preserving water and agriculture activity, including changes in soil and irrigation management practices, and changes in the use of farm input and natural resources. The cost induced by water scarcity, a highly probable effect of climate change, was assessed. The experience from this initiative confirmed that the design of policies and measures capable of saving water and increasing quality, while preserving the economic and social sustainability of agricultural systems, requires a clear
understanding of the complex relationships on various scales from the field/farm up to the catchment/basins. Such understanding was favoured by a combination of tools used by a multidisciplinary team with a strong involvement of local actors in an adaptive participatory process supported by adequate data. Prolonged interaction was necessary to develop a common language and mutual understanding; at the beginning a wide gap existed between water managers and scientists, since in the district, water allocation and management was based on previous experience and consolidated practices and water managers, apart from GIS, had little familiarity with modelling and tools. The success of the case study confirms that the political process-oriented nature of water management requires that how models and tools are to be used should be properly considered.

**Keywords:** Decision Support, Water, Agriculture, Climate change, Policy
Modelling approach for agriculture water management

Noemi Mancosu\textsuperscript{(1,2,*)}, Morteza Orang\textsuperscript{(3)}, Sara Sarreshteh\textsuperscript{(2,4)}, Richard L. Snyder\textsuperscript{(4)}, Donatella Spano\textsuperscript{(1,2)}

\textsuperscript{(1)}Dept. of Science for Nature and Environmental Resources (DipNET), University of Sassari, Italy
\textsuperscript{(2)}Euro-Mediterranean Center on Climate Changes (CMCC), IAFENT Division, Sassari, Italy.
\textsuperscript{(3)}California Department of Water Resources, Div. of IWMWUE, Sacramento, CA 94236, USA
\textsuperscript{(4)}Dept. of Land, Air and Water Resources, University of California, Davis, USA
\textsuperscript{(*)Corresponding author Email: nmancosu@uniss.it

Abstract:

The combination of long-term climate changes (e.g., warmer average temperatures) and extremes events (e.g., droughts) can have decisive impacts on water demand, with further implications on the ecosystems. The sustainable management of available water resources at the global, regional, and site-specific level is necessary, however, in countries already affected by water scarcity, it is becoming a crucial issue. In agriculture sector, the first step is to compute how much water is needed by crops in regards to climate conditions. Modelling approach can be a way to compute crop water requirement (CWR). In this study, the improved version of the SIMETAW model was used. The model is a user friendly soil water balance model, developed by the University of California, Davis, the California Department of Water Resource, and the University of Sassari. The SIMETAW# model assesses crop water requirements and generates hypothetical irrigation scheduling for a wide range of irrigated crops experiencing full, deficit, or no irrigation. The model computes the evapotranspiration of the applied water ($ET_{aw}$), which is the sum of the net amount of irrigation water needed to match losses due to the crop evapotranspiration ($ET_c$). $ET_{aw}$ is determined by first computing reference evapotranspiration ($ET_o$) using the daily standardized Reference Evapotranspiration equation and observed or simulated daily data. $ET_{aw}$ is computed as

$$ET_{aw} = CET_c - CE_o$$

where $CET_c$ and $CE_o$ are the cumulative total crop and effective rainfall values, respectively. Crop evapotranspiration is estimated as $ET_c = ET_o \times K_c$, where $K_c$ is the corrected midseason tabular crop coefficient, adjusted for climate conditions. The net irrigation amounts are determined from a daily water balance, using an integrated approach that considers soil and crop management information, and the daily $ET_c$ estimates. Using input information on irrigation system distribution uniformity and runoff, when appropriate, the model estimates the applied water to the low quarter of the cropped field (e.g., the 1\textsuperscript{st} quarter is the 4\textsuperscript{th} of the field receiving the least water). Employing the depths of water applied to the four quarters over the season, the actual evapotranspiration ($ET_a$) is estimated. Thus, computing the daily soil water balance, it simulates when the irrigation should be applied, estimates the number of irrigation events, and the water depth of each application. Moreover, setting the crop deficit irrigation and/or rain-fed conditions, the model estimates the reduction of yield relative to full irrigation. The SIMETAW# model has the ability to change the canopy resistance in response to CO$_2$ concentration, and the simulation allows it to adjust the $ET_o$ estimates for climate change. Therefore, the model can be used to assess climate conditions affecting crop production.
change impacts on future irrigation demand and propose adaptation strategies that potentially lead to a more sustainable water use. Results on the application of the SIMETAW# model in a case study will be discussed.

**Keywords:** irrigation demand, irrigation management, water productivity, adaptation strategies.
The Application of Simulation Models for Assessment and Impact Analysis of Drought and Water Requirements at Different Scales

Gerrit Hoogenboom (1,*), Melba Salazar (1), Jakarat Anothai (1), and Cecilia Tojo Soler (1)

(1) AgWeatherNet, Washington State University, Prosser, Washington 99350, USA
(*) Corresponding author Email: gerrit.hoogenboom@wsu.edu

Abstract:
Water is one of the most limiting factors for agricultural production, especially for rainfed cropping systems. Crops show an optimum performance when the amount of water lost by the crop and the soil surface are replenished on a daily basis through either rainfall or irrigation. However, under field conditions this rarely happens. Crops normally experience drought stress when the potential water loss through transpiration is higher than the available soil moisture for root water uptake. Given that transpiration and root water uptake are instantaneous and continuous, this can happen at a range of frequencies and durations, depending on available moisture in the soil profile, the type and stage of the crop and a range of other management and environmental factors. Determining the potential occurrence of drought stress is a challenge, especially for larger areas such as fields or even farms. Understanding the interaction of environmental factors, including weather and soil conditions, crop management, such as irrigation, and plant genetics is extremely complex. However, computer models that are based on the current state-of-the-art in crop and soil science can play an important role in understanding these interactions. Most crop simulation models simulate the dynamic growth and development processes of a crop as well as the soil and plant water balance, soil and plant carbon balance, the soil and plant nitrogen balance, and ultimately predict yield.

The Cropping System Model (CSM) is the simulation model that is part of the Decision Support System for Agrotechnology Transfer (DSSAT). DSSAT is a crop model application program that includes utilities for data processing, such as weather, soil and crop management data, application programs for short- and long-term simulations, and experimental data for over 25 of the most important agronomic crops, including grain cereals, grain legumes, vegetables, and sugar, oil, and tuber crops. The CSM model calculates a daily water balance that is based on demand and supply. Potential demand is calculated as a function of potential evapotranspiration using the Priestley-Taylor equation. Potential supply is calculated as a function of rooting depth, root length density, and soil water content of each individual soil layer. If the potential supply is at least as large as potential demand then no drought stress is simulated. However, if potential demand is greater than the potential supply, then drought stress is simulated. In the crop model drought stress affects a range of processes, including leaf expansion, photosynthesis, partitioning, and development.

CSM uses local environmental conditions as input, including local daily weather data, local soil profile and soil surface information, crop management, such as irrigation and planting date, and genetic information to define the crop and cultivar unique characteristics for growth, development and response to environmental conditions.
Using the crop simulation models, one can assess in-season drought stress and the need for supplemental irrigation or use the model for irrigation scheduling. The model can also be used to determine yield potential for a region as a function of long-term rainfall and temperature. Finally, the model can be used to determine the potential impact of climate change on local drought stress and its interaction with growth and development as well as final yield. Once the impact has been assessed, the model can also be applied to determine potential adaptation strategies to mitigate the expected negative impact of climate change on crop production. DSSAT and its underlying crop simulation models have been used for a wide-range of applications, including not only climate change and climate variability, but also famine early warning, irrigation management, water allocation management, genetics, and many others.

**Keywords:** DSSAT, Cropping System Model, Drought, Water Use, Climate
Aqua Crop as a decision support tool to assess the effect of field management on crop water productivity

Hanne Van Gaele(1,*), Dirk Raes(1), Jan Diels(1)

(1) KU Leuven University, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium
(*)Corresponding author E-mail: hanne.vangaele@ees.kuleuven.be

Abstract:

Due to the increasing world population and prosperity, global food production needs to increase by 70% by 2050. Since water is one of the major bottlenecks for improving agricultural productivity, upgrading crop water productivity is indispensable. Improved field management practices are one of the key solutions for upgrading (crop) water productivity. Especially in drought prone regions where crop production is determined by variable rainfall, dry spells and droughts rather than by low total rainfall, field management adaptations can make a big difference.

In this research the effect of different field management practices on yield (Y) and crop water productivity (WP_{ET}) was investigated by means of AquaCrop, a crop water productivity model developed by FAO. The effect of different field management practices was simulated for a variety of rainfed farming systems in semi-arid to subhumid regions. Those farming systems were represented by combinations of climate, seasonal rainfall (dry, normal and wet growing seasons), soil type, crop type (short versus medium or long growing cycles) and soil fertility level. The investigated field management practices comprised mulches, soil bunds, soil structure adaptations, rainwater harvesting and weed control.

Simulation results provided valuable insights towards the potential of upgrading crop (water) productivity by improved field management practices. A significant increase of Y and WP_{ET} (up to about 150% and 250% respectively) was simulated for mulches, soil bunds and rainwater harvesting while productivity decreased due to a restrictive soil layer and poor weed control. Moreover, the effectiveness of the different practices was compared for different climatological conditions of the semi-arid to subhumid range. Thereby it was observed that mulching and weed control pays off under all climatological conditions. In the driest conditions none of the investigated practices were effective so that (deficit) irrigation is required to increase productivity. In more humid conditions, practices that focus on saving water are less effective and therefore focus on other production limiting factors might be more appropriate. In between, mulches, rainwater harvesting and bunds were most effective, since they all increase water availability.

Although there is scope for further improvement of the field management simulation procedure of AquaCrop, the model proved to be a very powerful decision support tool. The effect of field management strongly depends on the complex interplay between climatological conditions, soil type, crop type and soil fertility level. Consequently, the selection of a suitable field management practice requires careful comparison of practices for local farming and environmental conditions. This can be achieved by...
means of scenario analysis with the AquaCrop model as was illustrated in this research. Moreover AquaCrop is able to account for the effect of climate change on crop production. This makes the model also a suitable decision support tool to compare the effectiveness of different field management practices under future climatic conditions.

**Keywords**: AquaCrop, decision support tool, crop water productivity, field management, drought prone regions
Comparing AquaCrop and CropSyst models in simulating barley growth under different water and Nitrogen regimes. Does calibration year influence the performance of crop growth models?

Marie Therese Abi Saab(1,*), Mladen Todorovic(2), Rossella Albrizio(3)

(1) Lebanese Agricultural Research Institute, P.O. Box 90-1965, Fanar, Lebanon
(2) CIHEAM – Mediterranean Agronomic Institute of Bari (IAMB), Italy
(3) National Research Council of Italy, Institute for Agricultural and Forestry Systems in the Mediterranean (CNR–I.S.A.F.O.M.), Via Patacca, 85, – 80056 – Ercolano (NA), Italy
(*Corresponding author E-mail: mt tabsaab@lari.gov.lb

Abstract:

This work investigated the performance of AquaCrop and CropSyst crop growth models in simulating barley growth under three water (full irrigation, 50% irrigation and rainfed) and two nitrogen (high and low) conditions with a particular attention to the influence of calibration year on the modelling results. Three years (2006-2008) of data from the experimental work carried out in Southern Italy were used in this study. AquaCrop model was based exclusively on the water productivity (WP) engine normalized for reference evapotranspiration whereas Crop Syst used both solar radiation engine and water productivity engines for the simulation of crop growth. AquaCrop required the re-calibration of crop growth parameters under different nitrogen regimes whereas CropSyst used an internal module to adjust the impact of different nitrogen inputs. The models were calibrated for each of three years and then validated for two other years. The overall results pointed out that, for both models, most of crop growth parameters are conservative enough (almost constant) to be used in any of three years. This indicated that only one year of data could be enough for model’s calibration confirming the robustness and validity of the approaches adopted by both models. Nevertheless, the performance of the models changed in respect to the year of calibration, from one year to another (i.e. different weather conditions) and for different water and nitrogen regimes. The statistical analysis based only on final biomass and yield for all three years has shown that the performances of AquaCrop are slightly better than that of CropSyst independently on the year of calibration. This was particularly evident for the conditions of non-optimal water and nitrogen supply and could be attributed to several distinctive features of AquaCrop such as: i) the three-thresholds water stress function considering canopy growth, stomatal closure and canopy senescence, ii) the dynamic harvest index function linked to the crop water status, and iii) the model’s re-calibration for the conditions of non-optimal nutrient supply.

Keywords: crop growth modelling, water productivity, water stress, nitrogen deficit, Mediterranean conditions.
Calibration of CropSyst Model for Wheat Grown under Three Soil Conditions in Egypt

Samiha Ouda\(^{(1)}\), Tahany Nor El din\(^{(1)}\), Ahmed Osman\(^{(2)}\), Mohammed Karrou\(^{(3)}\), Atef Swelam\(^{(3)}\) and Theib Oweis\(^{(3)}\)

\(^{(1)}\) Water Requirements and Field Irrigation Research Department; Soils, Water and Environment Research Institute; Agricultural Research Center; Egypt
\(^{(2)}\) Soil Improvement and Conservation Research Department; Soils, Water and Environment Research Institute; Agricultural Research Center; Egypt
\(^{(3)}\) International Center of Agricultural Research in the Dry Areas (ICARDA)

(*) Corresponding author E-mail: samihaouda@yahoo.com

Abstract:

CropSyst model was calibrated for wheat planted at three sites in Egypt, with three soil conditions (clay, sandy and salt affected soil) and three different wheat cultivars, one in each site. In clay soil, wheat cultivar Gemmiza9 was planted on 2 raised bed lengths (25 and 50 m), 2 raised bed widths (0.65 and 1.30 m) and three nitrogen treatments (100, 85 and 75% of the recommended optimum dose). In the new land, wheat cultivar Giza168 was planted under three irrigation amounts (125, 100 and 75 of ETc) and two nitrogen treatments (100 and 75% of the optimum dose). Whereas, in the salt affected soil, wheat cultivar Sakha93 was planted on flat bed and two raised bed widths (100 and 130 cm) and two nitrogen fertilizer doses (75 and 100% of optimum dose). The results of the calibration indicated that the cultivar-specific parameters were different for the three wheat cultivars in each site. The calibration results also showed that CropSyst model predicted wheat grains and biological yield, as well as water consumptive use with high degree of accuracy for the three cultivars at the three sites. In the clay and sandy soil locations, the model was able to simulate the effect of the treatments on soil moisture depletion and drainage, as well as nitrogen uptake by the plants. Furthermore, in the salt affected soil, the model was capable of simulating salinity distribution in the soil profile after the second and the third irrigation. The results implied that the calibration of CropSyst for these three cultivars grown under different soil conditions could be very important for other researchers to build on and develop management practices to increase irrigation water and land productivity.

Keywords: crop growth modelling, wheat, CropSyst, salt affected soils.
Design guidelines for surface irrigation modernization in Hetao Irrigation District. An application of the DSS Web Sad Reg

Miao Qingfeng (2), José Manuel Gonçalves(1,*), Carla Mendes(1), André Muga(1), Paula Paredes(1), Shi Haibin (2), Luis Santos Pereira(1)

(1) CEER - Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Tapada da Ajuda, 1349-017 Lisbon, Portugal
(2) The College of Water Conservancy and Civil Engineering, Inner Mongolia Agricultural University, Hohhot, China
(*)Corresponding author E-mail: jmmg@esac.pt

Abstract:

The Hetao irrigation district, located in the upper reaches of the Yellow River is one of the three largest irrigation districts of China, with 0.570 Mha of irrigated land. Traditional basin irrigation is the most representative irrigation method. Water resources allocated to the agricultural sector in the Yellow River basin are being reduced due to severe water scarcity and increased demand by the non-agricultural sectors, which implies irrigation modernization and adopting various water-saving technologies. General conditions of Hetao are adequate for surface irrigation due to the high charge of sediments on irrigation water, farmer’s knowledge, high compatibility with the canal conveyance and distribution network, and appropriateness to leach salts. The new technologies of surface irrigation, including the modernized furrowed and flat basin irrigation systems, land leveling and improved water use management, allied with the cropping pattern adjustment, offer feasible solutions for irrigation modernization well adapt to local conditions.

As it is well known, the performance of surface irrigation systems highly depends upon its design and farmers’ management. A variety of aspects make the decision process quite complex, often out of the farmers experience and empirical knowledge. The DSS methodology exploring the capabilities of irrigation modeling may contribute to improve design and management procedures. The Web-based DSS WebSadReg aims at designing and selection of farm surface irrigation systems. Through several simulation and computational tools, it produces a set of design alternatives based upon the user options, and ranks those alternatives relative to irrigation performance and environmental and economic impacts using multicriteria analysis. Its Web capabilities allows better flexibility, improving the user support to database access and enlarging the number of users and is an easy way to transfer knowledge and tools to the practice. This study aims the design guidelines for Hetao surface irrigation modernization, and its objectives include: (i) field surface irrigation characterization relative to soil hydraulic properties, crop water and irrigation requirements, the actual irrigation practices, land parcels description - size, slopes and water supply - economical data on irrigation (water, labor costs, yield prices); (ii) models parameterization for irrigation design; (iii) the relationships between sector water distribution and field irrigation performance (considering the description of a sector test - area, fields, canals, distributors, controllers); (iv) the delivery system functioning and constraints during the irrigation
season and the peak period, as well as the conditions for water deliver to fields (discharge, duration, and frequency); (v) the decision-making analysis relative to surface irrigation improvement considering various development scenarios and respective decision variables, on-farm and sector economical analysis, as well as the application of multicriteria analysis for selection of scenarios, applying DSS WebSadReg.

This paper presents results field trials: (i) an evaluation of laser land leveling operation; (ii) basin irrigation evaluation with parameterization WinIsaReg; (iii) Soil infiltration characteristics from irrigation evaluation data, related seasonal variability and inverse mode optimization; (iv) main characteristics of the canal conveyance and distribution network with identification of main scheduling constraints; (v) development of irrigation modernization scenarios.

**Keywords**: surface irrigation modeling; irrigation design; decision support systems (DSS); multicriteria analysis; Hetao irrigation district
Design of sprinkler irrigation subunit of minimum cost with proper operation. Application at corn crop in Spain

Francisco Carrión¹, Amaro del Castillo¹, José M. Tarjuelo¹, Patricio Planells P.¹, Miguel. A.Moreno¹

¹Regional Centre of Water Research (CREA). Universidad de Castilla-La Mancha (UCLM.) Ctra. de las Peñas, km 3.2. 02071, Albacete.
(*) Corresponding author Email: Jose.tarjuelo@uclm.es

Abstract:

Matlab software named PRESUD (Pressurized Subunit Design) was developed to identify the optimum solid set sprinkler irrigation subunit design with a criterion of minimizing the annual water application cost per unit of irrigated area ($C_T$). This $C_T$ is defined as the cost per cubic meter of water applied to the soil for crop use, calculated as the sum of investment ($C_a$), maintenance ($C_m$), energy ($C_e$), and water ($C_w$) costs. In this study, only rectangular subunits are considered, using an iterative method for calculating the lateral and manifold pipelines. The effects of the main factors considered in the design (lateral layout and sprinkler spacing, emission uniformity of sprinklers (EU), slope, length and diameter of lateral and manifold, among others) are also analysed using an iterative method for the calculation of lateral and manifold pipes. Water cost ($C_w$) is the main factor that conditions the $C_T$. In the case of maize crop in Albacete, Spain, with 650 mm of net crop water requirements, $C_w$ comprises 75% of $C_T$. The subunit configuration that yields a minimum $C_T$, for $C_w=0.10$ € m$^{-3}$ is a sprinkler spacing of 15m x 15m with an average sprinkler working pressure $h_a=350$ kPa, even though the investment and energy costs are higher than in the case of sprinkler spacing of 18m x 18m with $h_a=300$ kPa. This can be attributed to a higher value for general application efficiency of irrigation system ($E_a$) in the first case, which requires a lower volume of water.

In cases in which the initial water energy is low (groundwater), the impact of the energy cost to pump the water from the source to the subunit inlet on $C_w$ can reach 40%, as in the case of Albacete (Spain), with $C_w= 0.1$ € m$^{-3}$ and a water table depth of 80 m. Therefore, it can be concluded that the energy plays an important role in $C_T$, reaching more than 50 % of $C_T$.

Results shows that the criterion of limiting $\Delta h= 20$ %, widely used when designing a sprinkler irrigation subunit, does not always lead to solutions of minimum $C_T$, and the use of tools such as PRESUD can help farmers reach better solutions.

The $C_T$ increases with the subunit size. However, this analysis has to be completed with the cost of the pipes that supply water to all subunits, valves and automation costs, among others, in order to consider all variables relevant to selecting the subunit size with minimum total cost.

Keywords: solid-set sprinkler irrigation design, water application cost, energy cost
Rainfed maize in Inner Mongolia: evapotranspiration partitioning and groundwater contribution

Yao Wu(1,*), Tingxi Liu(1), Luis S. Pereira(2,*), Paula Paredes(2), Limin Duan(1)

(1) College of Conservancy and Civil Engineering, Inner Mongolia Agricultural University, Hohhot 010018, China
(2) CEER-Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Tapada da Ajuda, 1349-017 Lisbon, Portugal
*Corresponding author: wuyao.will@163.com, lspereira@isa.utl.pt

Abstract:

Groundwater is the vital component for water requirement of vegetation in Horqin sandy area, which is located in northeastern Inner Mongolia, China. This study aimed to define the role of groundwater contribution in soil water balance as well as to assess water use and evapotranspiration of a maize crop in Horqin area. Field data, particularly soil water contents data, were used for simulations, which were performed with the model SIMDualKc using the dual crop coefficient approach. Two years of field data from Agula eco-hydrology experimental sites relative to maize were used for model calibration and validation. Field data of soil water content were observed with TDR. The soil water balance model SIMDualKc was calibrated with data collected in 2008 and validated with data of 2009; the calibrated crop, soil and groundwater parameters were obtained from calibration and used as input of the model during validation. The root mean square errors of estimate (RMSE) were 0.011 and 0.010 cm$^3$ cm$^{-3}$ respectively for 2008 and 2009. The modeling efficiency (EF) relative to calibration and validation were 0.88 and 0.80 respectively and the index of agreement $d_{IA}$ was greater than 0.95 for both years. These indicators show good predictions by modeling with SIMDualKc. Results from model calibration and validation allowed to estimate the adjusted basal crop coefficient ($K_{cb\,adj}$) for maize: 0.3, 0.85 and 0.45 for the initial, mid season and end season of crop development periods. The groundwater level was around 1.0 m depth. The model, through a calibrated groundwater contribution parametric function, produced estimations of the groundwater contribution (GWC), which varied from 0.1 mm day$^{-1}$ at the earlier and later crop stages up to 3.8 mm day$^{-1}$ in the mid season, when the evaporative demand was higher. The seasonal GWC simulated by model was 368 mm in 2008 and 212.15 mm in 2009, thus accounting respectively for 60.6% and 55.1% of the evapotranspiration ($ET_a$). Soil evaporation represented 16.7% and 17.4% of $ET_a$. Results achieved allowing further use of the model to support farm activities and to improve knowledge of water use processes in the area.

Key words: Model SIMDualKc, dual crop coefficients, evapotranspiration, Horqin sandy area, groundwater contribution.
Modelling maize deficit irrigation in Galicia (NW Spain)

Javier J. Cancela(1,*) , María Fandiño(1), Emma M. Martínez(1), P. Paredes(2), R. Rosa(2), Benjamín J. Rey(1), Luis S. Pereira(2)

(1) GI-1716 Proyect and Planification, Agroforestry Engineering Department- University of Santiago de Compostela, Escuela Politécnica Superior, Campus Universitario s/n. 27002 Lugo, Spain
(2) CEER – Biosystems Engineering, Universidade Técnica de Lisboa, Instituto Superior de Agronomia Tapada da Ajuda, 1349-017 Lisboa
(*)Corresponding author E-mail: javierjose.cancela@usc.es

Abstract:

In geographic areas with high economic dependence of dairy cattle, as in Galicia (NW Spain), livestock feed is based on the production of forage maize. The high production costs (seeds, fertilizers, treatments, machinery, energy) and climate variability in recent years lead to serious economic losses if the crop is not irrigated. A good management of water resources requires modeling of crop irrigation requirements in order to establish a schedule for deficit and supplement irrigation that ensure an appropriate yield of forage maize. Therefore, the impacts on production due to different levels of water stress at critical crop stages were studied. This study refers to a maize experiment with two treatments: rainfed and sprinkler irrigated (with irrigation schedule set by the farmer). Measurements included the soil water content, fraction of ground cover, plant height and yields obtained in the years 2010-2012. Two models were used: ISAREG (Teixeira and Pereira, 1992; Liu et al., 1998) and SIMDualKc (Rosa et al., 2012). ISAREG model was used for the evaluation of net irrigation requirements – NIR - and irrigation schedules (dose and application dates) for the period 1985-2012, using calibrated data obtained in previous studies in the area. Results showed that NIR required to avoid water stress range from 120 mm (1997) to 390 mm (1990). Establishing irrigation schedules that allowing a decrease of 30% of soil water depletion below the fraction for no stress (p) and doses of 30 mm per irrigation, usually with gun sprinklers, it resulted yield losses of 7% with a water use efficiency of 84%, and an average of 9 irrigations per year. However, the number of irrigations must be adapted to weather conditions of any given year. The SIMDualKc model, that performs the soil water balance with the dual $K_c$ approach, was applied for estimating crop evapotranspiration ($ET_c$), calculating a basal crop coefficient ($K_{cb}$), which represent the transpiration component of $ET_c$, and a soil evaporation coefficient ($K_e$). The model was calibrated and validated by comparing model simulated with TDR observed soil water content data in 2012. A good fit was obtained for $K_{cb\text{ ini}} = 0.15$, $K_{cb\text{ mid}} = 0.90$ and $K_{cb\text{ end}} = 0.30$. The $K_{cb}$ values were adjusted to the fraction of ground cover observed in the field. In 2012, the evaporation component of the irrigated treatment was 30% (99 mm) and the transpiration component was 70% (224 mm), whereas they were 54% (113 mm) and 46% (97 mm), respectively, for rainfed treatment. Results show that the rainfed treatment had yield losses of 50 to 75% compared to the irrigated treatment; similar values were obtained for various study years (2010-2012).

Keywords: single and dual Kc approach, scheduling, soil water content, supplemental irrigation
Calibration and validation of the Hydrus - 1D model to simulate soil water balance of maize under full and deficit irrigation

Maria G. Gonzalez1*, Tiago B. Ramos2, Reimar Carlesso1, Zanandra B. Oliveira1, Juliano D. Martins1, Paula. Paredes2, Mirta T. Petry1, Luis S. Pereira2

(1) Federal University of Santa Maria, Rural Science Center, Av. Roraima, Nº1000, Cidade Universitária - Bairro Camobi 97105-900, Santa Maria - RS, Brazil
(2) CEER – Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Tapada da Ajuda, 1349-017 Lisbon, Portugal
*Corresponding author, e-mail:marygaby956@gmail.com

Abstract:
The maize crop yields depend upon the local edafoclimatic conditions, on irrigation scheduling, and variety/hybrid. Thus, studies relative to soil water dynamics under field conditions, with emphasis on the water flows in the root zone are needed to improve irrigation management. With this propose the soil water fluxes model HYDRUS-1D was selected. The present study aims at the calibrating and validating the model using field observations, and evaluating its performance and output sensitivity using measured soil water values obtained at different soil layers. Field experiments were performed in the experimental plots of the Federal University of Santa Maria, Southern Brazil during 2011/12 maize growing season; irrigation treatments were performed in an area protected by a rainfall shelter. The need for irrigation was determined based on crop evapotranspiration using the single crop coefficient approach thus the crop evapotranspiration (ETc, mm) was obtained as ETo Kc, where ETo is the FAO-PM reference evapotranspiration (mm), and Kc is the single crop coefficient. The following irrigation strategies were performed: full irrigation i.e. fully satisfy the crop water requirements (100% ETc), slight deficit (70% of ETc), moderate deficit (50% ETc), and severe deficit (40% ETc). The irrigation applications were set to be schedule whenever the sum of the daily ETc reached 25, 38, 50 and 64 mm using a fixed irrigation depth of 25 mm. Thus the 1st treatment corresponds to full irrigation, mild (70%), moderated (50%) and severe deficit (40%). The soil water content was daily measured using a set of sensors FDR (Frequency Domain Reflectometer) with measurements in the following layer depths: 0-0.10, 0.10-0.25, 0.25-0.55 and 0.55-0.85 m. Soil hydraulic properties were determined by inverse optimization of the measured values of the soil water content. After proper calibration of soil hydraulic properties (using the equation of van Genuchten), the HYDRUS-1D model was used to predict the soil water balance components. Testing results show a good agreement between measured and estimated soil water contents, with high coefficients of determination (R2 higher than 0.7) and low errors of estimate (RMSE ranging 0.016 to 0.024 cm3 cm−3). Results also showed that water percolation was much lower for the severe, moderate and mild deficit irrigation treatments. Thus, the HYDRUS-1D model proved to be a suitable tool for simulating soil water distribution and can be used to improve irrigation management.

Keywords: Water flow; Parameter estimation; Simultaneous and sequential parameter estimation; Soil water balance
Solid-set sprinkler irrigation controllers driven by simulation models: opportunities and bottlenecks

Enrique Playán(1,*), Raquel Salvador(2), Cristina López(3), Sergio Lecina(4), Farida Dechmi(5) and Nery Zapata(6)

(1) Dept. Soil and Water. EEAD-CSIC. Avda Montañana, 1005. 50059 Zaragoza. Spain. enrique.playan@csic.es
(2) Dept. Soil and Water. EEAD-CSIC. Avda Montañana, 1005. 50059 Zaragoza. Spain. rsalvador@eead.csic.es
(3) Dept. Soil and Water. EEAD-CSIC. Avda Montañana, 1005. 50059 Zaragoza. Spain. mclomar@gmail.com
(4) Dept. Soils and Irrigation. CITA-DGA (Associated Unit to EEAD-CSIC). Avda Montañana, 930. 50059 Zaragoza. Spain. sergio.lecina@cita-aragon.es
(5) Dept. Soils and Irrigation. CITA-DGA (Associated Unit to EEAD-CSIC). Avda Montañana, 930. 50059 Zaragoza. Spain. fdechmi@aragon.es
(6) Dept. Soil and Water. EEAD-CSIC. Avda Montañana, 1005. 50059 Zaragoza. Spain. vzapata@csic.es

Abstract:

Farmers continue to show wide differences in irrigation water use, even for a given location and crop. Irrigation advisory services have narrowed the gap between scientific knowledge and on-farm scheduling, but their success seems to have been limited. Sprinkler irrigation performance is greatly affected by meteors such as wind speed, whose short-time variability requires tactical adjustments of the irrigation schedule. Mounting energy costs often require consideration of inter- and intraday tariff evolution. Opportunities have arisen which permit to address these challenges through irrigation controllers guided by irrigation and crop simulation models. Remote control systems are often installed in collective pressurized irrigation networks. Agrometeorological information networks are available in regions worldwide. Water Users Associations use specialized databases for water management. Different configurations of irrigation controllers based on simulation models can develop, continuously update and execute irrigation schedules aiming at maximizing irrigation adequacy and water productivity. Bottlenecks requiring action in the fields of research, development and innovation are analyzed with the goal of establishing agendas leading to implementation and commercial deployment of advanced controllers for solid-set irrigation.

Keywords: control, models, irrigation systems, irrigation districts
Session 5
Innovative data-acquisition and information and communication technologies
Satellite-based Irrigation Advisory Services: a common tool for different experiences from Europe to Australia

Guido D'Urso(1,*), Carlo De Michele(2), Francesco Vuolo(3), Michael Cutting (4)

(1) Dept. Agriculture, University of Naples Federico II, Via Università 100 Portici (NA), Italy
(2) Ariespace s.r.l., Spin-off University of Naples Federico II, Centro Direz. Is.A/3, Naples, Italy
(3) University of Natural Resources and Life Sciences (BOKU), P.Jordan Str.82, Vienna, Austria
(4) South Australian Murray-Darling Basin Natural Resources Manag.Board, Strathalbyn, S. Australia
(*) Corresponding author Email: durso@unina.it

Abstract:

The potentiality of Earth Observation techniques in supporting the management of land and water resources has been nowadays widely recognised, based on many years of multi-temporal and multi-spectral observations integrated with traditional ground reference data. More recently, Earth Observation techniques are transferred to operative applications for supporting land and water management.

In this paper, we present the current status of a satellite-based irrigation advisory system based on dedicated webGIS for farmers and district managers, in three different agricultural systems and environments: Southern Italy, Austria and Southern Australia. Maps of canopy development (Leaf Area Index, LAI, albedo and soil cover) are derived from high-resolution (20 m), multispectral radiometric satellite images, delivered in near real time (less than 36 hours) and processed by using in-situ agro-meteorological variables. The output of this procedure is: i) the calculation of a maximum evapotranspiration (according to FAO-56 direct method) which takes into account the crop variability at sub-plot scale; ii) the assessment of crop water requirements for a temporal interval of 7-9 days around the satellite acquisition date. The maps and suggested irrigation volume applications are timely published on a dedicated webGIS-site, with access restricted to growers and basin authorities, in order to better control the irrigation process and consequently improve its overall efficiency The adoption of this leading-edge technology represents an important step forward the implementation of E.U. Water Directive 60/2000. The key-points of this procedure are: a) personalised irrigation advice; b) timely delivery of the information.

Final users have provided important feedback on the usage of the information provided; i.e. farmers are able to recognize without difficulties their parcels on the images and they schedule the irrigations by taking into account the information provided. The crop heterogeneity captured by the high resolution images is considered as a valuable add-on information to identify the variability of soil texture and fertility, plant nutrition, or different performance of irrigation systems.

All the farmers have evaluated positively the usefulness of the information provided, and in most cases an increase of irrigation efficiency was achieved, because of the reduction of water volumes.

Keywords: remote sensing, WebGIS, crop water requirements, advisory services
Crop coefficients derived from METRIC and SIM Dual Kc models for discontinuous woody crops. A remote sensing application to a super intensive olive grove

Isabel Pôças\(^{(1,2,*)}\), António Nogueira \(^{(1)}\), Teresa Apaço \(^{(1)}\), Mário Cunha\(^{(2,4)}\), José Silvestre \(^{(1,3)}\), Francisco L Santos \(^{(5)}\), Luís S Pereira \(^{(1)}\)

\(^{(1)}\) CEER Biosystems Engineering, Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Tapada da Ajuda 1349-017 Lisboa, Portugal
\(^{(2)}\) Centro de Investigação em Ciências Geo-Espaciais (CICGE), Rua do Campo Alegre 4169-007 Porto, Portugal
\(^{(3)}\) INIAV I.P., Dois Portos, Portugal
\(^{(4)}\) Faculdade de Ciências da Universidade do Porto, Rua do Campo Alegre 4169-007 Porto, Portugal
\(^{(5)}\) Instituto de Ciências Agrárias e Ambientais Mediterrânicas (ICAAM), University of Évora, Largo dos Colegiados, Évora, Portugal
\(^{(*)}\) Corresponding author E-mail: ipocas@mail.icav.up.pt

Abstract:

A conventionally accepted approach for the estimation of crop water requirements is based on the use of reference evapotranspiration (ETo) and a crop coefficient. Crop coefficient values are tabulated for a wide range of agricultural crops and generally can be used in different regions and climates. However, in orchard crops, the crop density, plant spacing, as well as the vegetation height and canopy architecture, can be highly variable and thus the tabulated crop coefficients might require adjustment to the specific conditions. In such context, the estimation of crop coefficients based on the physical characteristics of the vegetation might be particularly useful. Satellite-based surface energy balance models have been successfully applied to estimate and map evapotranspiration (ET) and derive crop coefficients. The METRIC™ model, Mapping EvapoTranspiration at high Resolution using Internalized Calibration, is one of such models. METRIC has been widely used over an extensive range of vegetation types and applications, mostly focusing annual crops. In anisotropic canopies as in olive orchards, some adjustments in METRIC application related to the estimation of vegetation temperature and of momentum roughness length and sensible heat flux (H) for tall vegetation must be considered. Such adjustments include the use of the Perrier function based on leaf area index and tree canopy architecture, associated with an adjusted estimation of crop height, to obtain momentum roughness length estimates. It also includes the computation of radiometric temperature considering a three-source condition, thus differentiating the temperature of the canopy, the temperature of the shaded ground surface, and the temperature of the sunlit ground surface. In a different approach, the SIMDualKc model performs the soil water balance simulation with estimation of the actual crop evapotranspiration using the dual crop coefficient procedure from FAO 56, but also incorporating improvements regarding soil evaporation calculation and the use of a density coefficient to deal with discontinuous crops. The density coefficient adjusts the basal crop coefficient using a physical
description of the vegetation based upon the fraction of ground covered by vegetation, the crop height and a parameter representing the relative importance of ET to ETo per unit of horizontal vegetation surface, affecting ground cover. In the current study, the single-layer-blended METRIC model was applied to Landsat5 TM and Landsat7 ETM+ images to produce estimates of ET and further derive crop coefficients for different stages of the growing season in a super intensive olive orchard in Southern Portugal. Similarly, ET modelling was performed and crop coefficients obtained with the SIMDualKc model, considering all the adaptations for a sparse woody crop, needed to reproduce the real conditions. Crop coefficients derived from both models were compared. Additionally, the values derived from both approaches were also compared with crop coefficients tabulated and/or published in the literature.

**Keywords:** Density coefficient, Dual crop coefficients, Remote sensing, Sparse canopies, Surface energy balance
Crop evapotranspiration through the use of satellite images

Enrique Palacios-Vélez (1), Héctor Flores-Magdaleno (1)

(1) Professors from Colegio de Postgraduados, Montecillo, Mexico State, Mexico.
(*)Corresponding author E-mail: epalacio@colpos.mx

Abstract:

Agricultural production requires a large part of the available water resources in several regions of the world. An efficient water use requires accurate estimations of crop evapotranspiration (ETc). However an accurate ETc estimation is really difficult to achieve when large regions such as irrigation districts or complete watersheds are involved.

Satellite images are an alternative that can be used to estimate accurate crop ETc volumes. In the present study two known methods were used to estimate crop ETc. The METRIC is an image-processing model which was developed at the University of Idaho. In the METRIC model, ET is estimated as a residual of the energy balance equation, where net radiation, soil heat flux and sensible heat flux are estimated.

The second method used is based on reference ETo, estimated with meteorological variables measured at a weather station, and the estimation of the basal crop coefficient (Kc) as a linear function of the NDVI vegetation index, obtained from satellite images, so that ETc=Kc∗ETo.

Several reports have been presented by technical personal working in two international projects, financed by the European Commission, DEMETER (DEMoostracion of Earth observation TEchnologies in Routine irrigation advisory services) and PLEIADeS (Participatory multi Level EO-assisted tools for Irrigation water management and agricultural Decision-Support) in which this methodology has been used. The main problem of this methodology is to obtain the parameters of the linear relationship. The group of “Teledeteccion” from University Castilla La Mancha (UCLM), suggest the use of two parameters which seems to be valid for crops which totally cover the cropped area.

The main objective of this paper is to evaluate the two methods, using Landsat 7 satellite images and meteorological information from a weather station in the central part of Rio Mayo irrigation district, in the Sonora State, Mexico. In a sector of 7,200 ha of this district crop evapotranspiration of four of the most important crops, such as wheat, potatoes, chickpeas and safflower was calculated.

Results show some differences, which can be no significant, if adjustments are made to the linear relationships for Kc values for each type of crop, whose morphological characteristics are quite different.

Keywords: Crop evapotranspiration, Kc, METRIC, NDVI
Assessment of Soil Water Content based on Remote Sensing Techniques. 
Case study of kiwi Orchard in Portugal

Celestina M.G. Pedras\textsuperscript{(1,2)}, Maria Isabel Valín\textsuperscript{(2,3)}, Helena Fernandez\textsuperscript{(1,4)}, Fernando Martins\textsuperscript{(1,4)}

\textsuperscript{(1)} UALG, University of Algarve, Campus Gambelas 8005-139 Faro, Portugal
\textsuperscript{(2)} CEER, Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Portugal
\textsuperscript{(3)} ESA, Polytechnic School of Viana do Castelo, Refóios do Lima, 4990-706 Ponte de Lima, Portugal
\textsuperscript{(4)} MED, Soil Research Group, University of Seville, Spain
\textsuperscript{(1,2)} cpedras@ualg.pt

\textbf{Abstract:}

Soil water management plays an important role in the response of kiwi plants (Actinidia deliciosa). In Braga district (Portugal) soil moisture content is monitored in an orchard of Kiwi fruit as a routine parameter. Drip irrigation system is the method used, delivering water and nutrients in precise amounts, at controlled frequencies directly to the plants root zone. A proper management of soil water content, particularly in the scheduling of irrigation, will help to minimize the effects of both water deficits as well as over watering. This crop tends to have high water requirements and extends over a wide area in Portugal, requiring innovative solutions to achieve better benefits. The aim of this study is to establish observation method of soil and crop conditions using the remote sensing techniques. To assess the accuracy of soil moisture measurements from satellites, it is important to compare satellite image with ground truth data (namely the Frequency Domain Reflectometry - FDR - diviner 2000). The combination of multispectral satellite images, in particular red and near infrared bands, produces an image representative of vegetation vigour, density, and health. In this case study, Landsat satellite images (2010 to 2013), are used and it is calculated the Normalized Difference Vegetation Index (NDVI) for different periods of time, using the software Idrisi Taiga 16.03. The information of vegetation indices is crossed with data soil moisture, in situ, to establish a correlation between both of them. Thus, it allows improving the soil water content monitoring, in particular for the soil water balance optimization and their effect on kiwi fruit production.

\textbf{Keywords:} Remote sensing, kiwifruit, NDVI, Soil Water Content
Use of pyranometers for continuous estimation of ground cover fraction in orchards

A. Martínez-Cob(1), J. M. Faci(2), O. Blanco(2), E. T. Medina(2), K. Suvočarev(1)

(1) Est. Exp. Aula Dei (Zaragoza), Avda. Montañana 1005, 50015 Zaragoza, Spain
(2) Dpt. Suelos Riegos (Associated to CSIC), CITA-DGA, Avda. Montañana 930, 50015 Zaragoza, Spain
(*) Corresponding author Email: macoan@eead.csic.es

Abstract:

Ground cover fraction (GCF) is defined as the fraction of ground beneath the canopy covered or shaded by a crop near solar noon as observed from directly overhead. GCF is a useful variable that can be determined in a variety of experimental procedures performed at a field plot scale. GCF is usually measured in experimental field plots using ceptometers or digital imagery. The use of these techniques in the field requires the presence in situ of qualified workers and do not permit the continuous recording of GCF. Thus, only a small number of measured values of GCF are available along the season. A network of pyranometers located at the ground level and above canopy can be connected to a datalogger so a continuous series of global radiation values can be recorded for long periods of time without the presence of any staff. Continuous values of daily GCF can be worked out from those readings. This approach could be particularly useful at remote, unattended sites. Nevertheless, the feasibility of such measures must be evaluated as the main constraint is that the pyranometers must be placed nearby the plant rows to avoid possible damage by the machinery used in the farm. This work presents the daily GCF estimates from pyranometer readings ('pyranometer-driven' method, GCFpyr) at two experiments: a) Experiment I, at a table grape grown under a net, from February 2007 to November 2009; b) Experiment II, at a late peach orchard, from May to September 2011.

In the Experiment II measurements were taken for one full irrigated, ‘control’ tree and for one ‘deficit irrigation’ tree. The daily GCFpyr values were compared to measured values (‘reference’ method, GCFref) using either photographic techniques (table grape) or ceptometers (late peach). For computation of GCFpyr, solar radiation below and above the canopy was averaged for two time periods: a) two hours around solar noon; b) daytime period (8:00 to 18:00 Universal Time Coordinated, UTC). For both experiments, the results obtained with the ‘pyranometer-driven’ method improved when the solar radiation was averaged for daytime periods. For the table grape vineyard (daytime averaging period), the ‘pyranometer-driven’ method showed a good agreement with the GCFref values as shown by a mean estimation error (MEE) of 0.000, a root mean square error (RMSE) of 0.113, and an index of agreement (IA) of 0.967. For the peach orchard (daytime averaging period), the agreement of the ‘pyranometer driven’ method with the GCFref values was worse, particularly with the ‘deficit irrigation’ tree. MEE was 0.046 to 0.210, RMSE was 0.064 to 0.217, and IA was 0.863 to 0.232. The highest GCF attained, the larger measurement range for GCF
(which involves a larger variability of sun angle above the horizon) and the presence of the net above the table grape, were the likely reasons for the better performance of GCFpyr in this crop. Further research is required to develop more appropriate calibration equations of GCFpyr taking into account the whole range of GCF variability.

**Keywords:** Ground cover fraction, Woody crops, Global solar radiation, Estimation methods.
An approach for delineating homogeneous within-field zones using proximal sensing and multivariate geostatistics

Carla Landrum(1), Annamaria Castrignanò (2*), Tom Mueller (1), Demetrio Zourarakis(3), Junfeng Zhu(4)

(1) Department of Plant and Soil Science, University of Kentucky, Lexington, KY, USA
(2) Research Unit for Cropping Systems in Dry Environments, Via Celso Ulpiani, Italy
(3) Division of Geographic Information, Commonwealth Office of Technology, Lexington, KY, USA
(4) Kentucky Geologic Survey, University of Kentucky, Lexington, KY, USA

(*) Corresponding author E-mail: annamaria.castrignano@entecra.it

Abstract:

At the landscape scale, soil moisture distribution derives from an integration of hydrologic, pedologic and geomorphic processes that cause soil moisture variability (SMV) to be time, space, and scale-dependent. This study uses multicollocated factorial cokriging (MCFC) analysis to determine the spatial scale(s) in which soil properties and terrain attributes affect SMV and produce a scale-dependent delineation of the field into homogeneous zones. This technique uses a multivariate geostatistical approach to fuse multiple data sources collected at different sampling scales to characterize SMV. Data fusion becomes important when proximal sensing is used in tandem with more sparse direct sampling. Georeferenced sensing (e.g. such as geoelectric sensing and LiDAR) acquires rapid, real-time, reiterative, non-invasive, high resolution data over large spatial extents that are enriched with spatial, temporal and scale-dependent information. Because geoelectric and LiDAR measurements are sensitive to soil properties and terrain features that affect soil moisture variation, they are often employed as auxiliary measures to support less dense direct sampling. This study uses high resolution geoelectric and LiDAR data as auxiliary measures to support direct soil sampling (n=127) over a 40 hectare Central Kentucky (USA) karst landscape. Shallow and deep apparent electrical conductivity (ECa) were measured using a Veris 3100 in tandem with soil moisture sampling on three separate dates with ascending soil moisture contents ranging from plant wilting point to field capacity. Terrain features were produced from 2010 LiDAR returns collected at <1 m nominal pulse spacing. Exploratory statistics revealed 12 variables that best associate with soil moisture, including terrain features (slope and elevation), soil physical and chemical properties (calcium, organic matter, clay and sand) and geoelectric measurements (apparent electrical conductivity for each date). A linear model of coregionalization (LMC) was simultaneously fitted to the matrix of direct and cross experimental semivariograms of the 12 variables studied. The LMC consisted of 3 basic components: nugget, spherical (short range scale=40m) and exponential (long range scale=250m) where each component explained 17%, 22% and 60% of the total measured variation, respectively. Applying principal component analysis to the correlation matrix at each spatial scale produced a set of regionalized factors summarizing the variation at that spatial scale, which lends insight into the properties influencing SMV. Results suggest that soil
texture and OM drive the soil moisture variation under the soil moisture regimes observed. Mapping the long-range regionalised factor allows us to delineate the field into homogeneous zones. This study shows the potential for using proximal sensing and multivariate statistics to develop soil moisture management strategies under water stressed conditions.

Keywords: soil moisture variation, data fusion, multicollocated factorial cokriging, LiDAR, electrical conductivity
Evaluation of physiological and biometric parameters of potato (*Solanum tuberosum* L.) under different water regimes by proximate sensing

Aicha Hammaoui (1, *), Rossella Albrizio (2), Vito Buono (1),
Mladen Todorovic (1)

(1) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
(2) CNR – Institute for Agricultural and Forest Mediterranean Systems – Naples, Italy
(*) Corresponding author E-mail: aicha.hammaoui@gmail.com

Abstract:

A field experiment has been conducted in Southern Italy (Valenzano, Bari) under open field conditions to evaluate the use of proximate sensing techniques for monitoring potato (*Solanum tuberosum* L.) development and growth under different water regimes. Three water levels have been applied, rainfed (I₀), 50 % of irrigation requirements (I₅₀) and full irrigation (I₁₀₀), in order to assess the impact of water stress on the crop growth and physiology. The irrigation scheduling has been managed via an Excel-based irrigation tool that employed meteorological, soil and crop data for a day-by-day estimation of the soil water balance in the effective root zone. This study aims to establish a comprehensive dataset with different types of measurements in order to link a set of spectral vegetative indexes (such as Simple Ratio, Normalized Difference Vegetation Index, Soil Adjusted Vegetation Index and the Water Index) as well as the thermal crop water stress index (CWSI), with some eco-physiological and biometric crop parameters. The variations of the physiological functions of potato at different phenological stages have been monitored under the three water regimes. The preliminary results indicated that under the water stress a reduction of stomatal conductance is observed which affected the rate of photosynthesis, canopy cover and biomass production and yield. Both the CWSI and the Water Index have shown a high sensitivity to the level of plant water status, with a clear correlation with the level of stomatal conductance and other physiological parameters, confirming the reliability of the indexes to detect the relative level of water stress when properly applied at the leaf scale. On the other side, with respect to the VIs applied at canopy scale, the spectral vegetation indices NDVI and SAVI showed generally a good level of correlation with leaf area index and fraction of ground cover, although NDVI seemed to reach a saturation level for values of LAI around 3, while SAVI seems to require a better parameterization of the effect of the soil background under the different levels of effective ground cover. Based on these preliminary findings, it can be confirmed that proximate sensing techniques and derived indexes could be powerful and effective methods to support the real-time monitoring of crop water status for a more appropriate irrigation scheduling.

**Keywords:** Vegetation indices, CWSI, potato, stomatal conductance, irrigation scheduling
Reference evapotranspiration estimation for the Mediterranean region using reanalysis datasets

Tayeb Raziei(1,2*), Diogo Martins(1), Isabella Bordi(3), Arash Parehkar(4), Mladen Todorovic(5) and Luis S. Pereira(1)

(1) CEER-Biosystems Engineering, Institute of Agronomy, University of Lisbon, Lisbon, Portugal
(2) Soil Conservation and Watershed Management Research Institute (SCWMRI), Tehran, Iran,
(3) Department of Physics, University La Sapienza of Rome, Rome, Italy
(4) Amirkabir University of Technology, Tehran, Iran
(5) Mediterranean Agronomic Institute of Bari, CIHEAM, Valenzano (BA), Italy
* Corresponding author Email: tayebrazi@yahoo.com

Abstract:

Estimating grass reference evapotranspiration using FAO Penman-Monteith method (PM-ET\textsubscript{o}) requires maximum and minimum air temperature, surface net radiation, relative air humidity, wind speed, and air pressure data. These data are usually not available for many land areas over the globe and when they exist access to them is often very difficult. The present study examines the utilization of the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis blended with gridded datasets for the computation of PM-ET\textsubscript{o} in the Mediterranean region. The PM-ET\textsubscript{o} time series computed with the blended reanalysis datasets are compared with those obtained using observations at selected stations through the region and results proved that the NCEP/NCAR datasets well performed for estimating PM-ET\textsubscript{o}. The spatial pattern of the annual mean PM-ET\textsubscript{o} using the blended reanalysis datasets agrees with those based on observations documented in the literature. The overall results suggest that the blended reanalysis data appears suitable for the estimation of ET\textsubscript{o} in the Mediterranean region although additional comparisons with observations are required.

Keywords: evapotranspiration, Penman-Monteith reference evapotranspiration (PM-ET\textsubscript{o}), NCEP/NCAR blended reanalysis datasets
Estimating reference evapotranspiration using weather forecast data in Southern Brazil

Zanandra B. de Oliveira², Mirta T. Petry¹, Reimar Carlesso¹*,
Luis S. Pereira³, Milene S. Teixeira¹

¹Agriculture Engineering Department, Federal University of Santa Maria, Av. Roraima, N°1000, Cidade Universitária - Bairro Camobi 97105-900, Santa Maria - RS. Brazil.
²Farroupilha Federal Institute, Rodovia RS 527, 98130-000, Julho de Castilhos, RS, Brazil.
³CEER – Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Tapada da Ajuda, 1349-017 Lisbon, Portugal.
*Corresponding author, e-mail: reimar.carlesso@gmail.com

Abstract:

Accurate estimation of reference evapotranspiration (ETo) is important in agricultural studies and water resources management, due to the fact that this estimation is required for crop water demand, especially for irrigation scheduling and water management in different crop management situations. The estimation of daily ETo can be realized based either on real-time meteorological data or a historical meteorological observed data series or predicting its values using the forecast weather data. Recent researches indicate that the weather forecast data are useful in predicting the ETo or its forecasting. Thus, this prediction is important and useful for an adequate irrigation management where weather stations are scarce or it is difficult to measure and access the necessary data in real time, helping farmers scheduling their irrigation, saving water, energy, and time. The objective of this study was to estimate the daily ETo (defined as ETo observed) and the ETo for the next four days, using the Penman-Monteith equation (PM-ETo), based on numerical weather forecast data, download from public Institute web pages (defined as ETo predicted). This study was based on weather forecast data collected from October 31st, 2011 to March 05th, 2013, downloading the data, daily at 6:00 AM, from the Tempo Agora webpage (www.tempoagora.com.br) for the city of Santa Maria, Brazil. The forecast weather data included air temperature, minimum and maximum temperature (Tar, Tmax e Tmin), relative humidity and wind speed. The solar radiation was estimated using the Hargreaves radiation equation (Hargreaves and Samani, 1982), with a KRs = 0.16, proposed by Allen et al. (1998). Thus, these values were used to estimate the ETo predicted. ETo observed was estimated using data collected from an automatic meteorological station (Waisala, model MAWS 301) installed in Santa Maria. The following indicators were used to evaluate the precision of the meteorological data used to estimate ETo (ETo observed and ETo predicted): Index of Agreement (d) developed by Willmott (1981), determination coefficient (R²), mean error (ME) and Root Mean Square Error (RMSE). The forecast air temperature data for the next four days presented a good agreement with the collected temperature data (d and R² higher than 0.7 and 0.36, respectively). However, the comparison between observed and predicted data for relative humidity and wind speed data resulted in lower fitness indices than air temperature (d less than 0.6 and R² near zero). Results also show a reliable goodness between et o observed and et o predicted, with values of d and R²
higher than 0.8 and 0.49, respectively. Besides, the values of RMSE and ME were lower than 1.43 and 0.56 mm dia-1, respectively. These values of ME indicated a slightly overestimation of the \( \text{et}_0 \) predicted for this region. These results clearly indicate that the \( \text{et}_0 \) predicted can be used to scheduling irrigation, been a powerful tool for farmers, water resources management, irrigation perimeters users and also for several crop management practices.

**Keywords:** reference evapotranspiration, weather forecast data, Southern Brazil, water management.
Developing an intelligent overhead irrigation system for high quality horticultural field crops

Jerry Knox, Andre Daccache*, Tim Hess, and Keith Weatherhead

Cranfield Water Science Institute, Cranfield University, Bedford, MK43 0AL, United Kingdom
* Corresponding author: a.daccache@cranfield.ac.uk

Abstract:

In northern Europe, irrigation of field vegetables has changed relatively little over the last 3 decades, but rising energy costs and supermarket demands for premium quality produce are forcing farmers to address the impacts of irrigation variability (non-uniformity) on crop quality, whilst simultaneously reducing energy and water consumption. This is not just a UK issue, but an international priority often termed as achieving ‘more crop per drop’. In England, field-scale vegetables and potatoes are the most important crop sectors in terms of irrigated area and crop value. Nearly three-quarters of the national area is irrigated using overhead methods (hosereels fitted with rainguns) with which are considered to be inefficient in energy and water use, with consequent impacts on crop quality. Whilst drip irrigation can improve water efficiency and crop quality in some sectors it is not the solution for field-scale horticulture, where sequential plantings and rotational cropping are more suited to portable overhead systems. Changes in water regulation are also impacting on crop production, with water availability and reliability becoming major constraints on horticultural businesses. Farmers now have to demonstrate ‘efficient and sustainable use of water’ to renew their abstraction licences (permits) and comply with retailer (supermarket) protocols for quality assurance and product traceability. Developing innovative approaches to combine knowledge of soil, crop and equipment management practices to reduce the variability in crop quality through precision irrigation is thus an industry priority.

In 2010, a new UK agrifood industry led project (Hortlink HL0196) was established to develop an intelligent irrigation management system for horticulture, integrating new technologies in soil moisture sensing, wireless communication and variable rate irrigation (VRI) to improve crop quality and reduce water consumption and other environmental impacts. The research has involved (i) assessing in-field soil heterogeneity using electromagnetic induction (EMI) and spectrometry technologies, (ii) testing a real-time wireless sensor system for monitoring changes in soil water status; (iii) evaluating the implications of water stress timing and severity on crop (onion and lettuce) productivity and quality, and (iv) engineering and testing a prototype for variable rate irrigation application on a boom irrigator. The technologies have been tested on-farm to evaluate their practicality, agronomic performance and economic viability to improve water efficiency, crop yield and crop quality. The key findings from the research and implications for improving on-farm irrigation management will be discussed.

Keywords: precision irrigation; EMI scanning; variable rate irrigation; lettuce; crop yield
Determination of leaf area index in vineyard using Unmanned Aerial Vehicles (UAV)

Rocío Ballesteros(1), José Fernando Ortega(1), David Hernandez(2), Miguel Ángel Moreno(1,*)

(1) Regional Centre of Water Research (CREA). UCLM; Ctra. de las Peñas, km 3,2. 02071, Albacete; Spain
(2) Instituto de Desarrollo Regional (IDR). UCLM; Campus Universitario s/n. 02071, Albacete; Spain
(*) Corresponding author E-mail: MiguelAngel.Moreno@uclm.es

Abstract:

Green canopy cover (GCC) plays a key role in energy exchange processes between the plant and the atmosphere, being necessary its determination when characterizing crop growth and development. Thus, it is an essential variable to describe the agronomic, biological, environmental, and physiological processes of the crops. Many other vegetation indices can be obtained from measures of the GCC, such as leaf area index (LAI), dry and wet biomass, among others.

There are many aspects of crop management that benefit from aerial observation. Unmanned aerial vehicle (UAV) platforms are evolving rapidly from technical and regulatory standpoints. Diagnostic information derived from images collected from on-board sensors, such as biomass, Leaf Area Index (LAI), disease and water stress can thus inform decision-making in crop management, yield forecasting, and environmental protection.

The aim of this work is to develop and validate a methodology to measure GCC in irrigated vineyard (Vitis vinifera L. cv. Cencibel) and rain-fed vineyard (Vitis vinifera L. cv. Airén) using UAV, and to establish the relationships with many other vegetation indices that are more complex to measure directly, such as LAI. The validation is performed in Tarazona de La Mancha (Albacete, Spain), in two commercial plots between 0.7 and 1 ha, where conventional cultivation techniques were applied by farmers. Vineyard cv. Cencibel was irrigated using drop irrigation systems.

Five samples in different dates were obtained to evaluate the evolution of the different parameters along the crop cycle. Sample date selection was also related to the main growth and development stages and significant changes in GCC. For each sample, a flight with an UAV (microdrones md-400) mounting a RGB camera was performed. After the flight, one plant for each variety and for each sampling date was evaluated, measuring parameters in all leaves, such as length and width, which allow estimating LAI using different mathematical models used in other researching studies. The obtained images were treated using conventional photogrammetry processes and software to obtain an orthoimage and a Digital Elevation Model (DEM) for each of the five dates. A specific software for GCC extraction from the orthoimage was developed, named LAIC, which clusters the RGB values to automatically extract vegetated and not vegetated areas of the orthoimage.
The analysis of GCC obtained from the orthoimage together with the values of LAI, permitted to obtain different models to relate GCC with LAI, being a third polynomial the model that best fits the obtained data for Vineyard cv. Cencibel and for cv. Airén.

**Keywords:** Leaf Area Index, Green Canopy Cover, Unmanned Aerial Vehicle, Vineyard
Automatic analysis of multiple Beerkan infiltration experiments for soil Hydraulic Characterization

Simone Di Prima\(^{(1,\ast)}\)

\(^{(1)}\) Dipartimento di Scienze Agrarie e Forestali, Università di Palermo, Viale delle Scienze, Italia
\(^{(\ast)}\) Corresponding author E-mail: simone.diprima@unipa.it

Abstract:

The BEST (Beerkan Estimation of Soil Transfer parameters) procedure of soil hydraulic characterization appears promising for intensively sample field areas with a reasonable effort both in terms of equipment and time passed in the field. Two alternative algorithms, i.e. BEST-slope and BEST-intercept, have been suggested to determine soil sorptivity and field-saturated soil hydraulic conductivity from a simply measured cumulative infiltration curve. With both algorithms, calculations have to be repeated also many times, depending on the number of collected infiltration data, that should vary between eight and 15. The need to consider a varying number of infiltration data is related to the fact that the infiltration model used in BEST is valid for the transient phase of the process, and only experimental data representative of this phase of the infiltration process have to be selected. The fitting of the theoretical model to the data is carried out by minimizing the sum of the squared residuals between estimated and measured infiltration data. Therefore, analyzing a single run may demand a lot of time, since many calculations have to be carried out. This circumstance complicates soil hydraulic characterization based on an intensive soil sampling, and it also increases the risk to make mistakes. These problems are expected to be substantially reduced, or even eliminated, if an automatic procedure of data analysis is applied. The general objective of this investigation was to develop an automatic data processing tool to easily and rapidly analyze databases including several BEST runs. The developed tool makes use of the Microsoft Excel Solver add-in routine. A Visual Basic for Applications (VBA) macro was written to automate creation and manipulation of Microsoft Excel Solver models. A looping structure was used in the VBA macro to automate data analysis of BEST experiments. The developed tool can be viewed as a practically useful contribution to an expeditious, intensive soil hydraulic characterization, also in terms of analysis of the collected data.

Keywords: Soil hydraulic properties, Measurement methods, BEST (Beerkan Estimation of Soil Transfer parameters) procedure, Automatic data processing tool
Stem water monitoring of mesquite (*Prosopis juliflora*) using dielectric soil moisture probes in Sudan

Tadaomi Saito(1,*), Misaki Inagaki(2), Hiroshi Yasuda(3), Kiyotsugu Yoda(4), Koji Inosako(1), Mohamed. A. Elbasit(5), Ahmed. M. Eldoma(6), Hiroshi Nawata(7)

(1) Faculty of Agriculture, Tottori Univ., 4-101 Koyama-Minami, Tottori 680-8553, Japan
(2) Graduate School of Agriculture, Tottori Univ., 4-101 Koyama-Minami, Tottori 680-8553, Japan
(3) Arid Land Research Center, Tottori Univ., Hamasaka 1390, Tottori 680-0001, Japan
(4) Faculty of Science and Engineering, Ishinomaki Senshu Univ., Ishinomaki, Miyagi, 986-8580, Japan
(5) College of Forestry and Range Science, Sudan Univ. of Science and Technology, Khartoum Sudan
(6) Desertification Research Institute, National Center for Research, Khartoum, Sudan
(7) Research Institute for Humanity and Nature, 457-4 Motoyama, Kamigamo, Kita-ku, Kyoto 603-8047, Japan

(*)Corresponding author E-mail: tadaomi@muses.tottori-u.ac.jp

Abstract:

Trees in arid and semi-arid regions have several functions to make efficient use of limited water resource to survive harsh conditions. One of the main functions is to control timing and quantity of water uptake, transport, storage and transpiration. The objective of this study is to clarify the water use strategy of trees in an arid environment through soil and stem water monitoring. The target tree is mesquite (*Prosopis juliflora*) in Sudan. *Prosopis* (mesquite) is a genus of “multi-purpose” tree, native to South and Central America and the Caribbean, which has been introduced widely into arid and semi-arid regions of the world. *Prosopis* avoids water stress under severe drought conditions by tapping water from the ground water table using deep tap roots and acquires greater drought tolerance with osmotic or stomatal adaptations. Such morphological and/or physiological properties facilitate rapid invasion by *Prosopis* in arid and semi-arid environments, causing various problems in many countries.

The research site was a mesquite forest in Soba, beside the campus of College of Forestry and Range Science, Sudan University of Science and Technology, Khartoum, Sudan. Annual precipitation of the site is about 150 mm and rainy season is from Jun to September. Two dielectric moisture probes (GS3: Decagon Device Inc.) were installed to the stems of two mesquite trees (4 and 7 cm in diameter, respectively) to monitor stem water content in Jun 2012. Since the outputs from the probes were severely affected by temperature, calibration equations were developed using time series of output data from the site and applied to reduce temperature dependency of the probes. Another type of dielectric probes (5TM: Decagon Device Inc.) were set at 5, 15 and 30 cm depths around root zone of the mesquite trees. Also, sap flow of 8 mesquite trees using Granier sensors, ground water level and meteorological conditions have been monitored from Nov 2011 in this site.

The results from the dielectric probes installed in the stems showed that the stem water content increased with increase in the soil water content below 15 cm deep after heavy rainfall events. The stem water content stated decreasing when the soil water potential
fell below the primary wilting point of the soil blow 15 cm deep. These results indicating that the mesquite trees used soil water below 15 cm deep in the rainy season, although they are regarded as to use ground water through deep tap roots. The water content in the stem 7 cm in diameter increased about 0.15 m$^3$m$^{-3}$ in the rainy season and maximum value was 0.46 m$^3$m$^{-3}$. On the other hand, the change in the water content in the stem 4 cm in diameter was small and the variation was within 0.05 m$^3$m$^{-3}$. The velocity of the sap flow stared increasing after sunrise and decreased once around noon (midday depression) when the soil was dry. This is because mesquite can close their leaves and reduce root water uptake and transpiration due to leaf orientation movements under high temperature and light intensity conditions.

**Keywords:** stem water content, capacitance sensor, sap flow, soil moisture, mesquite
Using remotely sensed data to induce snow cover dynamics and water productivity for sustainable water management in Ibrahim River Basin, Lebanon

Talal Darwish(1,*), Amin Shaban(1), Ivan Portoghese(2), Michele Vurro(2), Roula Khadra(3), Sagedah Saqallah(3), Laurent Drapeau(4), Simon Gascoin(4)

(1) National Council for Scientific Research, Remote Sensing Center, P.O. Box 11-8281, Beirut, Lebanon
(2) Consiglio Nazionale delle Ricerche, IRSA – UOS di Bari, viale F. De Blasio 5, 70132 Bari, Italy
(3) CIHEAM, IAM-Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
(4) Centre d’Etudes Spatiales de la Biosphère, CESBIO, 18 Av. Edouard Belin (bpi 2801) 31401 Toulouse cedex 9, Toulouse, France.
(*)Corresponding author E-mail: tdarwich@cnrs.edu.lb

Abstract:

Among the countries of the East Mediterranean, Lebanon is distinguished by snow cover expanding on its mountain chains for a season lasting between November and March. Considering the characteristics of the mountainous rocks (i.e. sinkholes, fissured and karstified limestone); however, the pedo-climatic and land cover conditions are affecting the hydrological regime which is directly responding to the area and temporal distribution of snow cover, which appears after two months from snowing events. This is reflected on water productivity and the related disciplines (i.e. agricultural yield, floods, etc). Despite some models link the water balance with snow and climate; however, previous studies did not explore the effect and linkage between the snow cover areas and the measured water discharge along coastal watersheds. Using moderate-resolution satellite images (MODIS-Terra) in this study enabled assessing the relationship between snow cover area, distribution and probability with the discharge of Ibrahim River Basin, which is a typical Lebanese watershed with an area of 326 km² stretching between the sea over slopping and steep lands to the east. Image analysis of the mean and maximum monthly areas of snow cover between 2000 and 2012 is varied and the largest snow cover often exists in January-February with snow-free between June and November. Moreover, snow cover dynamics was compared with the discharge from the main springs (Afqa and Rouaisse) feeding the river. The relationship between mean monthly snow cover and springs discharge was induced and found to be in direct relationship. Therefore, comparing the measured water discharge at the river mouth, it was found to be higher than the discharge of the two main feeding springs. This indicates the contribution of groundwater in nourishing run-off rate, which is again in direct interrelation with snow melting at the upper bordering slopes and probably from neighbouring watersheds. Using this application will serve the probability of snow detection over the watershed and predicting the expected water flow regime and volume for better water management and flood risk preparedness.

Keywords: Snow melt, springs, groundwater, MODIS-Terra, East Mediterranean
Session 6
Irrigation technologies and management practices for environmental upgrading
Effect of the start-stop cycle of the drive towers of a pivot on the water distribution pattern

Nery Zapata(1,*), Sofiane Ouazaa(1), Javier Burguete(1), Alfredo Serreta(2), Enrique Playán(1) and Borja Latorre(1)

(1) Estación Experimental Aula Dei-CSIC. Avda Montañana 1005. 50059 Zaragoza. Spain
(2) Escuela Politécnica Superior, Universidad de Zaragoza, Ctra. Cuarte s/n, 22071 Huesca, Spain
(*)Corresponding author E-mail: v.zapata@csic.es

Abstract:

The simulation of centre-pivot performance has been the subject of research efforts since the 1960s. Pivot models frequently use empirical equations relating pressure and sprinkler radial application pattern in the absence of wind. Individual, stationary water application patterns are overlapped and the resulting water application is mapped in the field. In such models water application only depends on the centre-pivot radius. These models use constant pivot tower angular velocity, neglecting the effect of tower switches on the start-stop cycles controlling pivot alignment. In this work the discontinuous pivot tower movement has been experimentally characterized and modeled. A detailed kinetic analysis of a four-tower commercial pivot was performed in all irrigations of a crop season. Each tower was monitored using a high precision GNSS (model GS15 receiver Leyca Geosystems AG, Heerbrugg, Switzerland), recording tower positioning at a high frequency. A post processing of the recorded data was performed with a RTK reference station to ensure positioning errors lower than 0.10 m. For different pivot travel speed, the start-stop cycles of the last tower and the average lineal speed of each tower were characterized. The angles between pivot sections driving the start-stop alignment cycles were experimentally determined. Two pivot radii were monitored during 12 irrigation events. Collectors were linearly arranged along them at a distance of 2 m. Irrigation uniformity was derived from these measurements. Experimental determination of the tower start-stop cycles at high pivot travel speeds requires recording the tower position at a minimum frequency of 1 s⁻¹. Lower frequencies would mask results. The experimental determination of start/stop angles resulted in a high standard deviation, complicating the analysis. A chaotic movement model, characterized by random control angles (belonging to the observed statistical distribution) seems to be the most adequate modeling strategy. In a further research, the simulation and comparison of the water distribution pattern between pivots with continuous travel speed or start-stop cycles will be addressed.

Keywords: pivot, mechanical movement, irrigation uniformity.
Evaluating and Modeling solid-set sprinklers irrigation of the field borders

Ouazaa Sofiane (1,*), Burguete Javier (1) and Zapata Nery (1)

(1) Dept. Suelo y Agua, Estación Experimental de Aula Dei (EEAD), CSIC, Apdo. 13034, 50080 Zaragoza, Spain
(*) Corresponding author E-mail: sofiane.ouazaa@eead.csic.es

Abstract:

Numerous studies have analyzed the solid-set sprinkler irrigation system performance. However, in the literature the effect of the field borders irrigated by no-fully circle sprinklers has not been considered in the whole-field performance. The objectives of this study are 1) to characterize two different solutions to irrigate the field borders (full circle sprinkler equipped with a deflecting plate, DP, and partial circle sprinklers, PC); and 2) to calibrate and validate the ballistic model parameters to adequately simulate their functioning. Two types of experiments were designed; the firsts were carried out with an isolated sprinkler under no windy conditions and at three pressure levels (200, 300 and 400 kPa). The second experiments were performed in a square solid-set sprinkler layout (18 m by 18 m) under three pressure levels (200, 300 and 400 kPa) and two levels of wind speed (lower than 2 m s\(^{-1}\) and between 2 and 4 m s\(^{-1}\)). The first experiments permit to characterize the radial curves of the sprinklers and the drop size distribution parameters. The second experiments were designed to complete the calibration and validation of the model and to experimentally compare both solutions at the same time under equal technical and meteorological conditions The results of the second experiments indicate that PC sprinklers perform better (larger uniformity) than DP sprinklers in the field border and that the magnitude of the differences were affected by the wind intensity and its direction. The ballistic model presented in Playán et al., 2006, once calibrated and validated with the experimental data, adequately simulate the PC sprinkler functioning. To reproduce the functioning of DP sprinklers the ballistic model has been modified to incorporate the jet impact with the deflecting plate and its effect on the drop size distribution.

Keywords: Sprinkler irrigation, ballistic model, water distribution, field borders, sprinkler deflecting plates.
Performances of subsurface drip irrigation compared to a raingun irrigation system for maize under water-restrictive conditions in a Mediterranean climate

Rami Albasha(*) , Jean-Marie Lopez, Jean-Claude Mailhol, Pierre Ruelle

National Research Institute of Science and Technology for Environment and Agriculture (Irstea), Montpellier, France
(*) Corresponding author E-mail: rami.albasha@irstea.fr

Abstract:

Under water shortage conditions, it is of major importance to find and assess the most water-saving irrigation techniques ensuring sustainable crop production. An experimental research was conducted on maize (Pionner PR35Y65) during four crop cycles, between 2008 and 2012, on a loamy soil at the experimental station of the Irstea research institute, SE France, to evaluate agronomic performances of subsurface drip irrigation (SDI) compared to a raingun irrigation system (RG) under mild and severe water-shortage conditions.

In 2008 and 2009, two drip line spacing, 160 cm (SDI-160) and 120 cm (SDI-120), were used in comparison to RG irrigation under a mild water-shortage condition by applying irrigation to satisfy 70% of maximal crop evapotranspiration requirements (MET). In 2011 and 2012, three drip line spacing 80 cm (SDI-80), 120 and 160 cm, irrigated at 80%MET, were used in comparison to an RG treatment, irrigated at 100%MET. In addition, another SDI-120 plot was added to be compared to an RG treatment at 50%ETM irrigation level.

Results analysis was performed using 5 performance indicators; grain yield (Y), harvest index (HI), total water use (TWU), water productivity (WP=Y/TWU) and irrigation water productivity (IWP =(Y-Y_non-irrigated)/Irrigation). In addition, for the inter-annual comparison of results, an attempt was undertaken to normalize yields for climatic demand as proposed by Steduto et al. (2007).

Results of all four years indicated a better performance with SDI compared to RG irrigation, especially under severe water-shortage conditions, which was in agreement with similar studies conducted on corn and other grain crops (Colaizzi et al., 2004; Lamm et al., 2012).

SDI yields were about 8% higher compared to RG under mild water-shortage conditions and almost 20% higher under severe water-shortage conditions in 2012 (850 and 1020 g/m², for RG-50%ETM and SDI-120, respectively). Yield differences were partly explained by higher HI values under SDI compared to RG (50% and 55% for SDI and RG, respectively). As expected, yields increased with less drip line spacing. Similarly, WP and IWP were higher for SDI compared to RG. In 2008 and 2009, WP ranged from 2.2 to 2.4 and 2.7 kg/m³/ha for RG, SDI-160 and SDI-120, respectively. Four-year-averaged WP was similar for RG and SDI-160 (2.4 kg/m³/ha) but 20% and 40% lower compared to SDI-120 and SDI-80, respectively. For all four years, IWP ranged from 3.2 kg/m³/ha for RG treatment to 3.7, 4 and 4.2 kg/m³/ha for SDI-160, SDI-120 and SDI-80 treatments, respectively.
Regarding the normalization of yields, this method did not change differences in performances among treatments. Nevertheless, normalization tended to over-estimate yields in dry years, changing the slopes of WP and IWP. Using normalized yields in WP and IWP remains questionable as the denominators in these indicators normalize implicitly yields as it comprise irrigation and rain terms, which in term are directly related to ETM and biomass production.

We conclude that under prevailing climatic conditions for a loamy soil, considering the balance between investments costs and profit of SDI system with different lateral spacing, SDI-120 is the best choice for maize irrigation under water deficit conditions.

**Keywords:** Subsurface Drip Irrigation Raingun Irrigation, Comparative analysis, Irrigation Performance, Water Productivity.
Effects of drip, sprinkler and basin irrigation on microclimate and fungal infection in winter wheat in the North China Plain

Yuxuan Wang\textsuperscript{(1,*)}, Shamaila Zia\textsuperscript{(1)}, Zhenfang Hu\textsuperscript{(2)}, Xiongkui He\textsuperscript{(2)}, Joachim Müller\textsuperscript{(1)}

\textsuperscript{(1)} Institute of Agricultural Engineering (440e), Universität Hohenheim, Germany
\textsuperscript{(2)} Centre for Plant Protection Machinery and Application Techniques, China Agricultural University, China
\textsuperscript{(*)} Corresponding author Email: yuxuan.wang@uni-hohenheim.de

Abstract:

Drip and sprinkler irrigation as water saving technology has already proved to have higher water use efficiency compared with surface irrigation methods. However, the basin irrigation method is still the most predominate irrigation method in North China plain (NCP) though the region faces severe water shortages. The main fungal diseases in winter wheat in NCP are fusarium, septoria and powdery mildew which has caused substantial damage to crops leading to loss of yield. The occurrence of fungal diseases depends on the climatic conditions during certain growing stages. However, it is not known yet if the micro-climate under drip sprinkler and basin irrigation leads to different risk of fungal disease infestation in winter wheat or not. This study made one step further to fill this knowledge gap by investigating the micro-climate under drip sprinkler and basin irrigation on winter wheat in NCP during the crop growing season in 2012. The experiment was conducted at Wuqiao experimental station which is located in Hebei province. Drip and sprinkler irrigation water requirement was calculated based on E\textsubscript{To} from FAO Penman-Monteith method. The data logger sensors (Voltkraft DL-121TH) measuring air temperature and relative humidity were installed under drip, sprinkler and basin irrigation in the field at three different heights of 15cm, 40cm and 100cm above ground from jointing stage until harvest. Infrared thermal images were taken regularly to determine the canopy temperature. The influences of three different irrigation methods on micro-climate at different plant heights were compared. The results show significant differences (p<0.05) among three irrigation methods at the same height during the whole experimental period. In addition, a multiple linear regression (MLR) was done to determine which parameters in terms of air temperature, air water content, wind speed, solar duration and days after irrigation influenced most the plant micro-climate under different irrigation methods. The results show that the RH at 15cm under basin irrigation was the highest at the end of boot stage and kept at around 90% till the end of booting stage. There’s a higher risk for basin irrigated crops to be infected by septoria and powdery mildew which attack the lower leaves in spring under longer period of high RH. The RH at 15cm plant height under sprinkler irrigation from heading stage till the end of the experiment was the highest among other irrigation methods and it indicated a higher risk for fusarium infection which tends to cause infections on the plants under favorable weather condition during flowering and grain formation.

Key words: irrigation, fungal infection, fungal microclimate, thermography
Simulation of water flow and heat transport in a drip-irrigated onion under plastic mulch

Jianhua Zheng\(^{(1,2)}\), Guanhua Huang\(^{(1,2,*)}\), Jun Wang\(^{(1,2)}\), Quanzhong Huang\(^{(1,2)}\), Haijun Liu\(^{(3)}\)

\(^{(1)}\) Center for Agricultural Water Research, China Agricultural University, Beijing 100083, China
\(^{(2)}\) Chinese-Israeli International Center for Research and Training in Agriculture, China Agricultural University, Beijing 100083, China
\(^{(3)}\) College of Water Sciences, Beijing Normal University, Beijing 100875, China
\(^(*)\)Corresponding author E-mail: ghuang@cau.edu.cn

Abstract:

Drip irrigation, in particular under the plastic mulch, is an effective approach for water conservation in arid and semi-arid regions. Understanding water distribution and soil heat transport is crucial for the mulched drip irrigation design. In this study, we focused on characterizing the water movement and soil heat transport in the drip-irrigated onion field using HYDRUS-1D model. The model was calibrated using the field experimental data of 2010, and validated by field observation in 2009. Three indicators, viz. root mean square error (RMSE), mean relative error (MRE) and model efficiency (ME), were jointly used to assess the model’s performance. The predicted soil water content and soil temperature are in good agreement with the field observation both in two growing seasons. The values of RMSE, MRE and ME in different soil layers ranged from 0.023 to 0.041 cm\(^3\) cm\(^{-3}\), 0.039 to 0.110 and 0.54 to 0.73 for soil moisture, and from 1.68 to 4.06 °C, 0.023 to 0.122 and 0.37 to 0.82 for soil temperature. The RMSE and MRE values for soil temperature in the surface soil layer were higher than other point due to its greater variation which might be caused by the effects of plastic mulch. The results indicated that the calibrated and validated model can be a useful tool for predicting soil water content and heat flow in the mulched drip-irrigated onion field.

Keywords: drip irrigation, soil water dynamics, heat transport, HYDRUS, plastic mulch
Modeling and Simulating Flow Transient in Pipeline Systems: Pump Combined with Closed Surge Tank

Itissam Abuaziah¹ *, Ahmed Oulhaj¹, Anas Abbassi Saber¹ and Nidal Shakarneh²

¹ Rural engineering department, Agronomic and Veterinary Medicine Hassan II Institute, Rabat, Morocco
² Electrical engineering, Al-Quds University, Jerusalem, Palestine

* Corresponding author Email: itissam2002@yahoo.com

Abstract:

Fluid transient analysis is one of the more challenging and complicated flow problems in the design and operation of water pipeline systems (wps). When transient conditions "water hammer" exists, the life expectancy of the wps can be adversely impacted, resulting in pump and valve failures and catastrophic pipe ruptures. Transient control has become an essential requirement for ensuring safe operation of wps. An accurate analysis and suitable protection devices should be used to protect wps. This paper presents the problem of modeling and simulation of transient phenomena in wps based on the characteristics method. Also, it provides the influence of using the protection devices to control the adverse effects due to excessive and low pressure occur in the transient. The developed model applied for main wps: pump combined with closed surge tank connected to a reservoir. The results obtained by using this model provide that the model is an efficient tool for water hammer analysis. Moreover; using the closed surge tank reduces the unfavorable effects of transients by reducing the fluctuations in pressure.

Performance of the microsplinkers with microtube nozzle as a Discharge controller

Alexsandro C S Almeida(1*), Ceres D G C Almeida(2), Tarlei A Botrel(3), José A Frizzone(3)

(1*) Universidade Federal da Grande Dourados, Unidade II, Rodovia Dourados à Itahum, Km 12, Caixa Postal 533, CEP79804-970, Dourados - MS - Brazil
(2) Universidade Federal Rural de Pernambuco (CODAI/UFRPE), AV. Francisco Correa, 643 São Lourenço da Mata, PE – 54.735-000, Brazil
(3) Universidade de São Paulo (ESALQ/USP), Av. Paduas Dias 11, Piracicaba – SP - Brazil

(*) Corresponding author: alexsandroalmeida@ufgd.edu.br

Abstract:

Microsprinklers emitters usually show water discharge variation along the lateral line due to the pressure variation. Self-compensated pressure emitters are used to compensate the pressure variation and reduce the discharge variation along the lateral. In general, diaphragms are used as a mechanism to control the water discharge in these emitters. Also this type of emitter allows designing longer lateral. However, self-compensated emitters are more expensive than no compensated emitter. Additionally, it is not possible to adapt diaphragms in no compensated pressure microsprinkler irrigation systems already installed in a field. In this study, a novel microsprinkler system is proposed that uses microtube as nozzle to compensate pressure changes along the lateral to give uniformity of emitter discharges. This work has the objective to adapt a microtube as a self-compensated nozzle into microsprinkler no compensated systems already installed in the field to improve the discharge uniformity along the lateral. Microtubes were adapted to three types of commercial microsprinklers (A, B and C). Tests were done both in the laboratory and field to evaluate the performance. A microtube with diameter of 1.5 mm was inserted in the microsprinkler nozzle. Microsprinklers were submitted to four different discharges: 40, 50, 60 and 70 L/h over a pressure range from 75 to 245 kPa. It was also evaluated the influence of the microtube in the water distribution around the microsprinklers. Experimental pressure head on different microsprinkler models were measured and compared to those obtained by Darcy-Weisbach and Blasius equations. Three models showed flow rates approximately 4% lower than calculated values. Lateral design was done by step-by-step procedure. The allowed variations of pressure on the lateral were inversely proportional to the emitter flow due to higher emitter flow rates require greater pressure to maintain flow rate for the same microtube diameter. The flow application uniformity for A1, A2 and B emitters by SU and DU coefficients were greater than 95%. Unlike of them, to C emitter the flow uniformity along the lateral line was 94 and 93 % for SU and DU, respectively. In general the emitters evaluated had coefficient of variation of flow rate (CVq) lower than 5.5%. This result indicates a good uniformity and distribution uniformity along the lateral are classified as excellent (> 90%). The original water distribution in the commercial microsprinkler did not change with the installation of the microtube as a nozzle. Spatial water distributions were similar to most of conventionally commercial microsprinklers. The microtube as a self-compensated nozzle showed to be technical feasible by reducing discharge variation along the lateral, even in great lateral...
line. They can be adapted to old microsprinklers systems already installed in the field. This advantage is not available in other self-compensated pressure mechanisms.

*Keyword:* microspinklers, self-compensated pressure emitters, application uniformity,
Small hydro power implementation in an existing irrigation network of a Water User Association (Southern Italy)

Angelo Nicotra(*), Vincenzo Tamburino, Demetrio Antonio Zema, Santo Marcello Zimbone

"Mediterranea" University of Reggio Calabria, Department “AGRARIA”,
Località Feo di Vito, I-89122 Reggio Calabria, Italy
(*) Corresponding author Email : angelo.nicotra@unirc.it

Abstract:

The availability of geodetic jumps in existing water distribution plants suggests the possibility and the convenience of their exploitation for electrical energy production at low cost in an environmentally sound way. This opportunity allows to provide additional economic resources for users thanks to the subsidies granted by the national energy policies for decreasing CO₂ emissions.

Small hydroelectric plants are today easy to be integrated in existing water distribution plants and can be managed at sustainable operation and maintenance costs. This is the case of many existing irrigation plants of Water User Associations (WUAs), where water availability out of the irrigation season can produce electrical energy by small hydro plants, in order to integrate the income of associated users.

However, procedures for installation and set up of these small plants should be further investigated on technical and economic approaches, in order to identify the most suitable solution for each specific case and provide indications to designers and users.

The paper reports an assessment of the technical feasibility and the economic performances of seven “micro-hydro plants” (i.e. with a power lower than 100 kW) in an existing irrigation network of a WUA (Consorzio di Bonifica Tirreno-Vibonese) located in Calabria (Southern Italy). The layout and longitudinal profile as well as the main features of the installed plants are presented.

A method based on a proper hydraulic function for sizing plant power and water discharge, maximising electrical energy yields, was arranged. An economic analysis allowed to identify costs and incomes on a 30-year financial plan.

The hydraulic jumps utilised by the micro-hydro plants varied between 38 and 89 m. The calculated electrical power and optimal water discharges were in the range 17-50 kW and 56-78 L/s. The annual energy production was 1.32 GWh, considering an operative period of eight months per year (which can be assumed as realistic, given the climatic and hydrological characteristics of the area). No particular modifications must be added to the existing irrigation networks.

The annual income from energy sale is 289 k€ in the first 20 years, when the energy price (including public subsidy) is on the average 0.22 €/kWh, and 92.4 k€ in the following years (with no public subsidy). The annual net profit (i.e. subtracting investment 20-year amortisation and maintenance/operation costs) is 0.13 €/kWh in the first 20 years and 0.03 €/kWh in the following period.
This study case showed the technical feasibility of integrating small hydro plants in existing irrigation networks of WUAs and its profitability when water is available during long time periods.

**Keywords**: geodetic jump, Water User Association, small hydro power, collective irrigation network, electrical energy production.
Linking Crop Water Stress Index (CWSI) and water stress coefficient (Ks) to support irrigation scheduling of wheat grown in Mediterranean environments

Vito Buono(1), Yamen Georges(1), Vito Cantore(2), Awadis Arslan(3), Mladen Todorovic(1,*)

(1) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
(2) Institute of Sciences of Food Production, CNR, Via Amendola, 122/O, 70125 Bari, Italy
(3) MAAR-GCSAR-ANRR, Damascus, Syria
(*Corresponding author E-mail: mladen@iamb.it

Abstract:

Wheat is among the crops that are affected by increasing drought and water scarcity, and deficit irrigation (DI) is considered to be an effective strategy to stabilize yields under limited water availability. To support on-farm DI management, methods based on soil water balance and canopy temperature measurements have been suggested to be reliable for field application. A preliminary experiment was set at CIHEAM-IAMB to evaluate the effect of different water regimes on two durum wheat varieties. In our experiment, under full irrigation (FI) the crop was kept quite constantly under unstressed conditions, while under DI (supported with 50% of corresponding FI supplies) and rainfed regimes, moderate water stress started respectively during the ‘early grain filling’ and the ‘booting to heading’ stages, subsequently increasing until the end of the cropping season. Grain yield reached 4.4 t/ha under FI, while it was reduced by only 14% in the case of DI treatment (3.8 t/ha) but with a corresponding potential water saving of about 44% (from 281 mm to 159 mm of total irrigation supplies). On the other side, DI increased yield of about 43% with respect to rainfed production (2.6 t/ha). The ‘biomass water use efficiency’ (WUE_b) decreased moving from rainfed (3.51) to FI treatment (2.42), and similarly the ‘yield water use efficiency’ (WUE_y) increased moving from FI (1.19) to DI (1.32) and to rainfed treatment (1.47). Midday canopy temperature (Tc) was remotely measured at plot scale by means of a thermal camera and the corresponding ‘empirical’ CWSI was computed. The CWSI followed the same daily trend for the two varieties and it appeared to be a good indicator of plant water stress as it was ranging between 0-0.1 under non-stressed conditions, while it increased steadily after the imposition of water stress, first for rainfed (at booting stage) and after for DI (at early filling stage), reaching values of 0.7-0.9 at the end of the season. A comparison of the ‘measured’ CWSI with the ‘simulated’ Ks has been done under the different water regimes, and the modification of some selected crop parameters resulted in the improvement of model simulations.

Key words: Wheat, water stress coefficient, CWSI, deficit irrigation, water use efficiency.
Crop water stress index for assessing irrigation scheduling of drip irrigated summer squash (\textit{Cucurbita pepo} L.)

Selçuk Özer$^{(1)}$, Yeşim Erdem$^{(2,*)}$

$^{(1)}$ Atatürk Soil, Water and Agricultural Meteorology Research Station, Kırklareli, Turkey

$^{(2)}$ Namık Kemal University, Agricultural Faculty, Biosystem Engineering Department, Tekirdağ, Turkey

(*) Corresponding author Email: yerdem@nku.edu.tr


crop water stress index (CWSI)

\begin{abstract}
This study was conducted to determine the possibility of a crop water stress index (CWSI) to schedule irrigation for summer squash (\textit{Cucurbita pepo} L.) grown with drip irrigation during the summer periods of 2010 and 2011. The effects of five irrigation levels which were applied based on a ratio of Class A pan evaporation ($k_{cp}$ = 0, 0.50, 0.75, 1.00, 1.25) on yields and resulting CWSI which was calculated by using the empirical approach were also investigated. The seasonal crop evapotranspiration for the 2010 and 2011 years changed as 222.4 – 472.2 mm and 300.8 – 575.8 mm, respectively. As a result of research, the highest squash yield was obtained in the first year from $I_{125}$ ($k_{cp}$ = 1.25) treatment as 34.80 t ha$^{-1}$ and the second year from $I_{100}$ ($k_{cp}$ = 1.00) treatment as 31.20 t ha$^{-1}$. The trends in CWSI values were consistent with the soil water content induced by deficit irrigations. Unlike the yield, CWSI increased with increased soil water deficit. An average threshold CWSI value of about 0.38 before irrigation produced the maximum yield. The yield was directly correlated with mean CWSI values and the linear equations “$Y = -37.12 \times \text{CWSI} + 44.475$” and “$Y = -18.338 \times \text{CWSI} + 34.726$” can be used for yield prediction. The CWSI value was useful for evaluating crop water stress in squash and should be useful for timing irrigation and predicting yield. Moreover, statistically significant correlations were found between CWSI and leaf area index (LAI).

Keywords: Summer Squash (\textit{Cucurbita pepo} L.), yield, evapotranspiration, crop water stress index (CWSI)
\end{abstract}
New Apulia Nitrates Action Plan: identification of suitable policies aimed to reduce water pollution and improve environmental sustainability on regional scale

Angelantonio Calabrese(1,*), Valeria Ancona(1), Vito Felice Uricchio(1), Claudia Campanale(1), Maria Antonia Iannarelli(2)

(1) Water Research Institute of National Research Council, via F.De Blasio 5, 70132 Bari, Italy
(2) Area Politiche per la riqualificazione, la tutela e la sicurezza ambientale e per l’attuazione delle opere pubbliche – Servizio di Tutela delle Acque – Regione Puglia, Viale delle Magnolie 6/9, Bari, Italy
(*Corresponding author E-mail: angelantonio.calabrese@ba.irsa.cnr.it

Abstract:

In 2005 Apulia Region approved the first Nitrates Action Plan (D.G.R. n° 2036) proposing the designation of regional Nitrates Vulnerable Zones (NVZs) caused by nitrates from agricultural sources, as required by the European Directive "91/676/CEE" and the National one’s (D.Lgs. 152/06). These polluted areas were confirmed in 2010 (D.G.R. n. 1317). Successively, in 2012, all the Italian regions have been called to update Nitrates Vulnerable Zones (NVZs) designation. Therefore, a detailed study has been carried out in order to investigate what has been change during the last four-year period (2008-2011) in which an elaborate regional water resources monitoring has been conducted. Data analyses and elaboration of all available monitoring results allowed to: (i) identify the main pollution sources emerging in the region, (ii) analyze the influence of previous policy actions evaluating their efficiency on the regional land, and last (iii) draft new suitable policies aimed to reduce the actual nitrates pollution evidenced during the last four years examined. In particular, it was found that a positive effect of the previous policy actions occurred in the reduction of some of the regional NVZs and, at the same time, new opportune mitigation strategies to control and manage nitrates pollution in the updated NVZs have been identified and proposed to improve regional environmental sustainability.

Keywords: nitrates pollution, monitoring systems, water policy
Managing modern irrigation technologies for the sustainable use of water in Mediterranean agriculture

Manpriet Singh(1,2,*), Ettore Capri(1), Jeremy Dyson(2), Romano De Vivo(2)

(1) Universita Cattolica del Sacro Cuore, Via Emilia Parmense, 84, 29122 Piacenza, Italy
(2) Syngenta, Schwarzwaldallee 215, 4002 Basel, Switzerland
(*) Corresponding author E-mail: manpriet.singh@unicatt.it

Abstract:

Water is a highly disputed resource on our globe. Increasing water shortages, due to erratic precipitation, prolonged droughts and non-sustainable water extraction, result in a future in which water may become an even more disputed resource (Wada et al. 2010, Iglesias 2006), especially if the available water has to be shared by more people. Politicians, industry and other institutions are encouraging the sustainable use of water resources in irrigated agriculture which is the largest consumer of fresh water resources (EEA 2009). In Europe’s Mediterranean countries, some irrigation systems use up to 80 per cent of all extracted fresh water resources in the region (IEEP 2000). This leaves little space for other uses in the same catchment area, including water used in urban areas and by terrestrial and aquatic environments which provide important ecosystem services. To improve the efficiency of irrigation systems, national governments, encouraged by the European Union, support the modernisation of irrigation systems (European Commission 2013): surface irrigation systems are replaced with (semi-)closed and pressurized irrigation systems, such as sprinkler and drip systems (Lecina et al. 2010, Playan and Mateos 1999). These are promising water saving technologies, which reduce evaporative losses and increase irrigation efficiencies by up to 90 per cent (Van Halsema and Vincent 2011). Modern irrigation technologies are promoted as tools that will help recover river flows and prevent depletion of groundwater aquifers, allowing more water to be available for ecosystems to remain intact (Barcelo et al. 2011, Puigdefabregas 2004). However, without adapting irrigation management practices, advanced irrigation technologies will not automatically lead to water savings. This paper reflects on recent literature and reviews the link between irrigation, environmental degradation and climate change in Europe’s Mediterranean countries. In our analyses we use primary data, collected from two irrigation systems in Southern Italy, to examine what good irrigation management practices are and how these relate to the performance of irrigation technologies. On-farm good practices that help farmers to improve the quality of drainage water and thus increase water availability are also elaborated upon. Our findings highlight the need to assess the performance and water saving potential of existing and new irrigation system technologies on the catchment level, rather than measuring on-field water use efficiencies. Our study emphasises the need to address good management practices to reach the intended outcome of new technologies, which in this case aim at booking real water savings to make more water available for other uses in the catchment area (Seckler 1996, Keller and Keller 1995). Currently, Europe’s policy for sustainable water use in irrigated agriculture is rather focussed on introducing new, on-field water-saving irrigation technologies without addressing how to manage these technologies, due to which policy does not
always translate into a practice in which ‘real’ water savings are made and more water is made available for other uses. Ideally, we would like to share the insights and conclusions of this paper with everyone who is involved in policy-making and interested in the interface between technology and management.

**Keywords:** irrigation modernisation, on-farm water management, sustainable water use, ecosystem services, European Policy
Session 7
Use of treated and low quality water in agriculture
Water4Crops: A twin project for Integrating biotreated wastewater reuse and agro-food wastewater valorization with enhanced water use efficiency to support the Green Economy in Europe and India

Antonio Lopez *

(*) Consiglio Nazionale delle Ricerche - Istituto di Ricerca Sulle Acque
Via F. De Blasio, 5 - 70123 Bari - Italy
Email: antonio.lopez@ba.irsia.cnr.it

Abstract:

Improving water use efficiency in face of the increased water deficit in agriculture requires a coordinated international approach with a strong commitment of all stakeholders (e.g. farmers, plant breeding industry, technology developers, etc.). The multiple issues related to water and agriculture are too often hampered by the lack of coordination and exchange of information. The treatment of water and elimination of pollutants is crucial for human health and environmental welfare. While there are a number of water cleaning methods available, the potential of biotechnology based on plants, micro-organisms or biochemical processes has not been yet fully exploited.

In this context, within its 7th Framework Program the European Commission on late 2012 co-funded with six million of euros the project “Integrating biotreated wastewater reuse with enhanced water use efficiency to support the Green Economy in EU and India”. Contemporarily, according to the call, the similar but not identical project “Integrating bio-treated wastewater reuse with enhanced water use efficiency to support the Green Economy in EU and India” was funded with more than three million of euros by the Indian Government through its Department of Biotechnology.

The twin projects whose acronym is “Water4Crops” in addition to the following main objectives: i) developing innovative biotechnological wastewater treatments for improved water recycling for agriculture; ii) improving water use efficiency at field level through agronomics, plant breeding and locally adapted irrigation technologies and techniques, are both specifically aimed at supporting the Green Economy in Europe and India. Such economy is the one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is an economy or economic development model based on sustainable development and a knowledge of ecological economics.

To actually contribute to implement such an economy, Water4Crops will develop an innovative modular biotechnological process dedicated to fully exploit the use of water and its content of the organic carbon and nutrients. This will lead to an innovative triangle with creation of extra added value compounds (organic acids, alcohols, PHA, ...) besides nutrients from agrofood industry- as well as municipal- wastewaters, wastewater reuse (both necessary to increase crop yield) and energy as last recovery in a cascade approach. Nutrients and water will go back to the land and create opportunities to increase crop yield and to allow new crops to grow (spreading harvest
periods and processing times). Finally the new crops and higher yields will allow more activities such as food processing and biorefinery. The co-creation of these new product combinations will lead to enhanced business opportunities.

Water4Crops provides for the first time an innovative combination of several technical improvements to bridge bio treatment of wastewater and increase water productivity with a transdisciplinary identification of agri-business opportunities and the related requirements for tailoring technological innovations.

The European consortium includes 22 partners from eight Countries: 5 Universities, 8 Research Institutes, 4 agro-industrial companies, 3 spin-off companies and 2 consultant companies. As for the Indian consortium it is made of 14 partners: 2 Universities, 6 Research Institutes, 6 agro-food industries or SMEs. The rationale behind the Water4Crops projects, their structure, their objectives as well as their expected results will be presented by the European project coordinator.

**Keywords**: green economy, water use efficiency enhancement, wastewater reuse, agro-food wastewater valorisation, plants breeding.
Properties of the filtrate from processing of the pig manure by filtration method

Zygmunt Kowalski(1,*), Józef Hoffman(2), Krystyna Hoffmann(2), Agnieszka Makara(1)

(1) Institute of Chemistry and Inorganic Technology, Cracow University of Technology, Warszawska 24, 31-155 Cracow, Poland
(2) Institute of Inorganic Technology and Mineral Fertilizers, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
(*)Corresponding author E-mail: zkow@chemia.pk.edu.pl

Abstract:

Properties of filtrate obtained from treated pig manure by worked out filtration method were presented the new proposed by us manure treatment method providing treatment of pig manure by mineralization and filtration. Pressure filtration is an efficient method aid enabled high the filtration rate 1300–3000 kg/m²/h of manure separation into solid and liquid fractions. Despite strong variations in chemical oxide demand COD (10,000–80,000 mg/L) and in suspended solid content SS (10,000–20,000 mg/L), the method was able to maintain an overall average removal performance from filtrate ~90% for the COD and > 99% for the SS. Mineralization process eliminates the odor intensity coming from the filtrate obtained in comparison to odor intensity coming from the pig manure. In the liquid fraction available nitrogen compounds, potassium, calcium, microelements and heavy metals were determined too. Filtrate contained even < 3500 mg/L COD. It is the concentration level obtained with use of some membrane processes to manure filtration. The analysis of main components showed that the chemical and biochemical characteristics of liquid fraction were dependent on the type of the technology used for separation. Treated filtrate could be used for artificial rain irrigation of crops or eventually as raw material for production of liquid fertilizer. If required, the filtrate may be also treated in conventional biological WWTP’s.

Keywords: pig manure treatment, filtration method, filtrate, microelements, heavy metals
Degradation of antibiotics in livestock wastewaters for environmental protection: laboratorial experimentation using ligninolytic fungi

Maria P. Amador(1*), Ruben M. Fernandes(2), Heleno Abreu(1), Isabel M. Duarte(1), Maria L. Brito(3), Mário P. Barreto(4), Maria C. Prudêncio(2)

(1) Departamento de Ambiente, CERNAS, Escola Superior Agraria de Coimbra, Instituto Politécnico de Coimbra, Bencanta 3040-316 Coimbra, Portugal.
(3) Laboratório de Microbiologia, CBAA/DRAT, Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Tapada da Ajuda 1349-017 Lisboa, Portugal
(4) Águas Mondego e Bairrada, S.A. – ETA da Boavista, Av. Dr. Luís Albuquerque, 3030-410 Coimbra, Portugal.
(*) Corresponding author E-mail: paula_amador@esac.pt

Abstract:

Antibiotics are substances produced by microorganisms that can destroy or inhibit the growth of other microorganisms. However, their presence in a natural environment can disturb the ecological balance. The widespread administration of antibiotics, for human and animal therapy, results in absorption, distribution, metabolising and excretion of the molecules through the urine and faeces, in their active forms, together with their metabolites. The agricultural systems have a particular interaction with the antibiotics in wastewater; on one hand the animal production sector is responsible for the contamination of rural wastewater with antibiotics, and on the other hand, they use potable and irrigation water that can contain antibiotic residues. These serious problems have been identified. High concentrations of antibiotics in the effluents of sewage treatment plants as well as in superficial waters have been frequently reported, the majority of which present a recalcitrant behaviour. Therefore, the conventional biological methods of wastewater treatment are not efficient as a result of the presence of antibiotics or aromatic pollutants, that inhibit microbial growth, lower the biodegradability of the pollutants in the wastewater, but also cause a selective pressure favouring the growth of bacteria increasingly multiresistant. The increasing awareness that the intensive use of antibiotics is responsible for the presence of a broad range of antibiotic residues detected by environmental monitoring, have been recently placed the concerns on the search for innovative biological treatments for sewage treatment plants. Such treatment should deal effectively and economically with wastewaters contaminated with antibiotics and the bacteria carrying antibiotic resistant genes. A research study is being developed testing an innovative method for antibiotics degradation using basidiomycetous fungus. These ligninolytic fungi are capable of degrading lignin, whose aromatic structure is similar to the molecular structure of some
pollutants. This capacity is due to the secretion of oxidative enzymes such as lignin peroxidase, manganese peroxidase, versatile peroxidase and lacasse. This research is developing a laboratory procedure using wastewater from two specific sites: livestock intensive production and human hospital, allowing a comparison and enlarging the range of antibiotics types in agricultural areas in Coimbra Region. This paper describes a research project that aims i) to characterize the emergence of resistant bacteria and resistance genes disseminated in microbial communality with higher potential risk, related with livestock units and human hospital; ii) to study the degradation of some more prevalent antibiotics using some white-rot fungi in in vitro assays; iii) to evaluate the practical utility of this method for degradation of antibiotics in field conditions to prevent environmental pollution and the spread of bacteria harbouring antibiotic resistant genes.

Keywords: Antibiotic, Antimicrobial resistant bacteria, Antibiotic ligninolytic degradation, Agricultural Water Resources, Livestock Wastewater
Macroscopic root water uptake under salt stress and non-uniform salt distribution: I. Column-scale experiments

S. Ouazaa\(^{(1)}\), G. Dragonetti\(^{(1)}\), N. Lamaddalena\(^{(1)}\), A. Comegna\(^{(2)}\), and A. Coppola\(^{(3)}\)

\(^{(1)}\) Mediterranean Agronomic Institute, Land and Water Division, IAMB, Bari, 70010, Italy
\(^{(2)}\) School of Agricultural, Forestry, Food and Environmental Sciences (SAFE), University of Basilicata, Potenza, 85100, Italy
\(^{(3)}\) Department of European and Mediterranean Cultures - Architecture, Environment, Cultural Heritage - (DICEM), Hydraulics and Hydrology Division, University of Basilicata, Matera, 75100, Italy
\(^{(*)}\) Corresponding author E-mail: sof_yen@hotmail.com

Abstract:

In this paper we investigated the possibility for monitoring simultaneously and continuously the relationship between the macroscopic crop response and the evolution of water content, electrical conductivity and root density along the soil profile during the whole growing season of a bean crop under different salinity treatments at column scale. Water storages measured by TDR sensors were used for calculating directly the actual water uptake by the root system along the whole soil profile under the different salinity levels imposed during the experiments. As expected, the EC\(_w\) increased more rapidly with the higher salt concentration of the irrigation water. Nevertheless, it was also observed that a higher water storage in the soil profile may be able to counteract the effect of increasing salt contents in higher salt concentration treatments. The particular crop behavior was mainly ascribed to the soil properties rather than only on the irrigation water quality. Differences in soil water retention changed drastically the response of crops to irrigation water salinity. In presence of higher water storages, the salt added at any irrigation finds higher water contents. The consequent dilution effect may be able to counteract the higher salt concentration of the irrigation water, keeping the soil water salinity EC\(_w\) below harmful values. The irrigation water salinity reduced the root volumes, not only the physiological effectiveness of the root uptake process.

Keywords: Irrigation water salinity, Root Uptake, Crop transpiration, Time Domain Reflectometry (TDR), Soil water flow and solute transport
Parameterizing macroscopic root water uptake under salt stress and non-uniform salt distribution: II. Field-scale experiments

N. Chaali(1), G. Dragonetti(1), D. Hijazeen(1), N. Lamaddalena(1), M. Todorovic(1), R. Albrizio(1), Comegna(2), and A. Coppola(3)

(1) Mediterranean Agronomic Institute, Land and Water Division, IAMB, Bari, 70010, Italy
(2) School of Agricultural, Forestry, Food and Environmental Sciences (SAFE), University of Basilicata, Potenza, 85100, Italy
(3) Department of European and Mediterranean Cultures - Architecture, Environment, Cultural Heritage - (DICEM), Hydraulics and Hydrology Division, University of Basilicata, Matera, 75100, Italy
(*) Corresponding author E-mail: antonio.coppola@unibas.it

Abstract:

Much of the crop response under saline irrigation depends on the root distribution over the root zone. In turn, this largely depends on whether the root system preliminary developed into a saline or non-saline profile. The salt distribution in the root zone depends, besides management practices and other environmental factors, on the complex non-linear processes of water flow and solute transport in soil determining variable distributions and storage of solutes and water along the whole root-zone, as well as their upward and downward fluxes. The effect of all these processes on the response of a crop to irrigation with saline water cannot be assessed without a detailed spatio-temporal monitoring of water contents and solute concentrations in soils during irrigation with saline water. An answer may be a methodology coupling adequate soil monitoring to numerical models simulating the transfer of water and solutes in the soil-plant-atmosphere continuum. A detailed monitoring allows following continuously the evolution of the local processes of water and salt storage and transport which mainly influence root uptake. By integrating such a database in numerical models, insights may be gained on the effects of the main physicochemical interacting processes affecting root-zone salinity and root uptake response to increasing osmotic potentials. Nevertheless, proper modeling and parameterization of the root water uptake as a function of water and salinity stresses remain one of the main challenges. The main reason for this is that the required data cannot be obtained easily and with the necessary detailed spatial and temporal resolution. Additionally, an accurate transpiration rate is required when validating the prediction capacity of the sink term functions in the numerical models. With such premises, this study has investigated the possibility for monitoring simultaneously and continuously the relationship between the macroscopic crop (tomato) response and the evolution of water content, electrical conductivity and root density along the soil profile during the whole growing season of a tomato crop under different salinity treatments. Water storages measured by TDR sensors were used for calculating directly the actual water uptake by the root system along the whole soil profile under the different salinity levels imposed during the experiments. It was observed that during irrigation with saline water the salt content increased along the whole profile but that it tended to accumulate quite uniformly below
the 20 cm in the case of the 4 dSm$^{-1}$ treatment and at depth between 15 and 25 cm in the case of the 8dSm-1 salinity treatment. Compared to the reference freshwater treatment, the evapotranspiration under salinity treatments started to decrease at a threshold value of the time-depth average electrical conductivity (EC) of soil water of about 3dSm$^{-1}$. Based on the results of soil and plant monitoring, the root uptake process was simulated by using a model for water and solute flow in the soil-plant-atmosphere continuum. This way, the root activity reduction at each depth-node was calculated as a function of the salinity (and eventually water) stress. This enabled relating the distribution of higher/lower activity of root uptake along the soil profile in response to the actual distribution of salts.

**Keywords:** Irrigation water salinity, Root Uptake, Crop transpiration, Time Domain Reflectometry (TDR), Soil water flow and solute transport modelling
Saline water use: effects on soil salinity and alfalfa production under date palms in the Algerian Oasis.

Cherfouh Rabia (1), Alkama Nora (1), Merouki Kame (1), Derridj Arezki (1)

(1) Faculté des Scs Biologiques et des Scs Agronomiques, University Mouloud Mammeri de Tizi-Ouzou, Algeria.
Corresponding author Email: rabiacherfouh@yahoo.fr

Abstract:

The management of water in the palm plantations in Saharan areas is considered as historical and cultural reference populations of the oasis. The alfalfa under palm tree allows an optimal exploitation of water and soil. The aim of this work was to investigate the doses and the frequencies of irrigation recommended for reducing salinity and hydrous constraint by integrating farmer's practices.

This study was conducted with alfalfa (Medicago sativa L.) and we choose Timacine, a genotype traditionally used by local farmers. We irrigate this plant with water of CE=7.8ms cm\(^{-1}\) using 3 doses of irrigations combined with 4 frequencies of irrigation. We measured the effects of irrigation water, on Timacine and salinity of the soil. Soils receiving leaching fraction of 30\% (D2) had salinity of 3.6ms. cm\(^{-1}\) in the soil layer of 0 to 60cm, whereas for the leaching fraction of 0\% (D0) and 15\% (D1), the average EC for the same depth was 5.9 and 4.5 ms cm\(^{-1}\) respectively. This shows that leaching fraction of 15\% involves a reducing of salinity about 25\% to 40\%. The salinity of the layer soil surface depend on the amount of leaching fraction, beyond, the effect of the ground water is dominating and the salinity of the deeper horizons is similar. Salinity of the soil was also influenced by frequency of irrigation. The frequencies F1 and F2 had a perceptible effect and emphasize the effective role of the amounts of leaching fractions. Under palm plantation when the interval between the irrigations is important the Stalinization of the soil solution is inevitable even if a great dose of water is irrigated.

In the palm plantation, the alfalfa plays an important role on foddering in oases agriculture. It has an agronomic and economic role and takes an active part in the development of the breeding because of its adaptation to salinity and dryness. Development of alfalfa depends on the climate and salinity of the soil. With 6 cuts, the best yield was 5 to 3.5Kg. m\(^{-2}\) and observed in the soils irrigated with D1 and D2 and the frequencies F1, F2. The weakest yield was lower than 3.4 kg. m\(^{-2}\) and obtained with the frequencies of irrigation F3 and F4 associated with the three amounts of leaching fraction considered. Out of station the farmers carry out 3 to 4 cuts per year and t 3 Kg m\(^{-2}\) of yield.

The results of this experimentation showed that changes in the control of the irrigations can improve the conditions of salinity and allow the cultures under palm tree an optimal development.

Keywords: saline water, irrigation, soil salinity, alfalfa.
Abstract:

The Middle East and North Africa region is the most water scarce region in the world. The region’s annual per capita water availability stands at 1,200 m$^3$, just barely above the internationally accepted poverty line of 1,000 m$^3$/capita/year. Due to an expanding population and growing economic sectors, the per capita water availability is expected to decline to alarming proportions in the coming decades. By the year 2050, two-thirds of MENA countries could have less than 200 m$^3$ of renewable water resources per capita per year. The competition for freshwater resources among economic sectors and the impacts of climate change all act as multipliers of the already existing challenges of deteriorating water quality and scarcity.

SWIM Sustain Water MED aims to address these challenges in the field of non-conventional water resources management. Non-conventional water sources, such as treated wastewater, rain- and storm water offer great potential to relieve the over-abstraction of freshwater reserves, prevent water source pollution as well as sanitary health risks. These in turn can lead to cost-savings and even economic opportunities.

The project is one of five Demonstration Projects implemented under the framework of the Regional Programme ‘Sustainable Water Integrated Management’ (SWIM) that is funded by the European Union (EU) and aims to contribute to the effective implementation and extensive dissemination of sustainable water management policies and practices in the southern Mediterranean region. SWIM Sustain Water MED is thus funded by the EU and co-financed by the German Federal Ministry of Economic Cooperation and Development. The project is implemented in a period of 3 years from 2012-2014 by a consortium of 8 project partners with the GIZ Jordan in the lead. It operates in four countries, implementing demonstration projects in Morocco, Tunisia, Egypt and Jordan. Each of the demonstration projects addresses a different aspect pertaining to non-conventional water resources management, including wastewater treatment and reuse as well as eco-sanitation and rainwater management.

In Jordan, the project implements a decentralized wastewater treatment unit at the newly constructed Head Quarters of the Public Security Directorate (PSD) in Moqablane, in the semi-urban suburbs of Amman. The project aims to reduce the freshwater consumption and thereby overall costs of PSD on one hand and on the other hand it aims to contribute to the national process of developing a solid strategy for
decentralized wastewater treatment and reuse management, there where it is more cost-efficient than the centralized system.

**Keywords**: Non-conventional water resources management, wastewater treatment and reuse, eco-sanitation, rain- and storm water management, regional network, capacity-building
On the effectiveness of reusing treated wastewaters by infiltration ponds in coastal farmlands. Preliminary investigation on insights from the Korba site, Tunisia

Habib Chaieb\textsuperscript{1*}, Rekaya Moncef\textsuperscript{1}, Nabiha Ouerfelli\textsuperscript{2}, Mario Laghi\textsuperscript{3,4}, Luca Magagnini\textsuperscript{3,4}, Omar Tosatto\textsuperscript{3,5}, Andrea De Angelis\textsuperscript{6}, Flavia Sollazzo\textsuperscript{6}, Pietro Teatini\textsuperscript{3,7}

\textsuperscript{1}DGRE - Direction generale des ressources en eau, Ministere de l'agriculture et de l'environnement - Tunis (Tunisie)
\textsuperscript{2}ONAS - National Office of Sanitation - Tunis (Tunisie)
\textsuperscript{3}CURSA - University Consortium for Socioeconomic and Environmental Research - Campobasso (Italy)
\textsuperscript{4}MED Ingegneria SRL – Ravenna (Italy)
\textsuperscript{5}M\textsuperscript{3}E SRL - Mathematical method and models for engineering - Padua (Italy)
\textsuperscript{6}IMELS – Italian Ministry for the Environment, Land and Sea - Rome (Italy)
\textsuperscript{7}Dept. DICEA - Department of Civil, Environmental and Architectural Engineering, Univ. of Padua (Italy)

\textbf{Abstract:}

Treated wastewater (TWW) reuse has increasingly been integrated in the planning and development of water resources in Tunisia. Specifically, the recharge of Korba aquifer (Cap Bon) by treated wastewater (TWW) via infiltration basin is monitored since December 2008 for the changes occurring in groundwater quality. The aim of the present paper, elaborated in the framework of the EU funded IMPROWARE Project (Innovative Means to Protect Water Resources in the Mediterranean Coastal Areas through Re-Injection of Treated Water) is to review the available data and investigate the impact of recharging a deteriorate aquifer by treated wastewater through infiltration ponds.

\textbf{Key words:} Aquifer recharge, Treated wastewater, Infiltration, Water reuse, Mitigation of saltwater contamination, Korba.
Water multi-purpose reuse case study: the Yarqon River Rehabilitation Project

Xavier Garcia (1,*), David Pargament (1)

(1) Yarqon River Authority, 9 Ussishkin Street, Tel Aviv, Israel
(1) Corresponding author E-mail: xavier.garciaacosta@udg.edu

Abstract:

The Yarqon, the river that flows through the Tel-Aviv Metropolitan Area, was once the second biggest in volume of flow in Israel. In the past, the annual discharge was 220 million m3 coming mainly from the springs maintained by a large karstic aquifer. After the creation of the State of Israel in 1948, followed by the intensive population growth and an increasing need to supply water also to the growing agriculture and industry, pumping from the aquifer increased and the river lost most of its spring flow. This and the increasing flow of poorly treated sewage, both urban and industrial, caused severe impact on the rivers' ecosystems. The attempt to change this began with creating the Yarqon River Authority (YRA) in 1988. In the last years the YRA has implemented several rehabilitation projects, such as the upgrading of the basin’s WWTPs in order to obtain high quality tertiary effluents to restore the flow of the river and its dependent riparian habitat. The effluents pass through a constructed wetland before discharging into the river. The actions conducted by the YRA have successfully changed the condition of the river itself and, in many aspects, transformed the riparian landscape of the river area from a “backyard” to a “front yard”. In addition, the Israeli Water Authority is implementing a water reuse project, based on the water flowing in the river, that will use membrane technology in order to facilitate irrigation of Tel-Aviv’s parks as well as parks in neighboring municipalities. The reuse system will also supply water to farmers who have water abstraction rights from the Yarqon, thus allowing more water to flow in the river. Therefore, the Yarqon River Rehabilitation Project (YRRP) depicts an interesting case of Integrated Water Resource Management (IWRM) in which the use of high quality effluents: a) improves environmental and ecological aspects in receiving bodies, b) provides amenities and improves the quality of life for urban dwellers, c) facilitates multi-purpose reuse and d) maximizes economic advantages.

The main objective of this paper is to analyze the YRRP from the perspective of the water resource management involving environmental, ecological and socio-economic aspects, and multiple-type water users and water sources. Firstly, the study synthesizes the main factors that caused the depletion and degradation of the river in which agriculture had a significant role. Secondly, the study illustrates how the change in the previous socio-political paradigm, in view of water scarcity in the region, determined the reuse of effluents for the ecological rehabilitation of the river, along with agricultural purposes. Thirdly, the study analyzes organizational aspects of the YRRP and shows the results of a preliminary monetary analysis of the benefits obtained through the project’s implementation to assess its potential in economical terms. The YRRP is an example of an attempt to manage water resources in a way that will provide environmental and ecological benefits while generating a substantial platform for improving the quality of life for the most heavily populated area in Israel and...
realizing economical benefits through the reuse of water, advanced treatment and supply to multiple type users.

**Keywords:** multi-purpose reuse, river rehabilitation, Yarqon River, water scarcity, IWRM
Agent-based study of stormwater re-use system operational capabilities during drought

Dragan Miličević(1), Borislava Blagojević(1,*), Slaviša Trajković(1)

(1) University of Niš, Faculty of Civil Engineering and Architecture, 18000 Niš, A. Medvedeva 14, Serbia
(*Corresponding author E-mail: borislava.blagojevic@gaf.ni.ac.rs

Abstract:

The multi-agent methodology presents an innovative approach in software engineering, social, economic, and environmental modeling. The multi-agent system has been created for utilizing stormwater control facilities i.e. water usage from retention/detention ponds at the site of Vlasina Lake, Serbia. The system has been chosen due to its capability to model dynamic processes. The model is developed in the Netlogo multi-agent programmable environment. The physical environment of the Vlasina Lake site model is realistic. The model illustrates the relationship between water availability and demand for secondary water use. There are two groups of agents: water source agents and water use agents. The group of water source agents consists of 17 ponds, while the group of water use agents comprise agricultural, communal, and tourist user. The intended water consumptions for water use agents are: agricultural land and park irrigation, washing roads and parking lots, and artificial snow production for ski trails. The goal of this paper is to assess the portion of water demand that could be satisfied from the stormwater re-use system during drought. We use the Standard Precipitation Index (SPI) to identify drought, and observed precipitation data in climatic scenario for model input. Contrary to usual model output as the accumulated inflow of water to the ponds and the accumulated water consumption, we take into account that the ponds can run empty and also have a maximum volume. We display a plot of the available water volume in the ponds and portion that will be used for each time step. This could be an useful tool for decision makers to understand both the consequences of changing the sizes of the ponds, and cost effectiveness of system during extreme water stress episodes.

Keywords: Agent based model, Drought, Water re-use, Water stress,
Hydrocarbons removal from water bodies using biogenic adsorbents

Kalliopi Chatzizaharia (1), Sofia Papadaki (1), Christina Tsiodra (1), Dimitrios Economides (1), Dimitrios Sidiras (2), Elias Dimitriou (3), Dimitrios Hatziavramidis (1*)

(1) School of Chemical Engineering, National Technical University of Athens, Heroon Polytechiou 9, 15780 Zografou, Greece
(2) Department of Industrial Management and Technology, University of Piraeus, 80 Karaoli and Dimitriou Str., 18534 Piraeus, Greece
(3) Hellenic Centre for Marine Research, Institute of Marine Biological Resource and Inland Waters, Anavissos Attikis, Greece
*Corresponding author Email: dthatzia@central.ntua.gr

Abstract:

In the present work, wheat straw, a lignocellulosic matter, has been investigated for its use as an adsorbent of hydrocarbons in water. Wheat straw is an agricultural residue that represents the 55% of total wheat production. Its adsorptivity depends on its structural and physicochemical features and particularly on the presence of lignin (20% w/w on dry basis). Specifically untreated and auto-hydrolyzed in optimum conditions wheat straw have been examined as hydrocarbon adsorbents. Oil spills were created in the laboratory by dispersing diesel and crude oil on water supplied from various Greek water bodies (lakes, rivers and marine waters). The efficiency of wheat straw as adsorbent was determined via analytical methods such as Thermogravimetric Analysis (TGA), Total Organic Carbon (TOC), Fourier Transform Infrared Spectrometry (FTIR), X-Ray Diffraction Analysis (XRD), Scanning Electron Microscopy (SEM), and Atomic Absorption Spectrometry (AAS).

Keywords: wheat straw, lignocellulosic, diesel, crude oil, XRD, TOC, FTIR, AAS, SEM,
Session 8

Climate change: adaptation and mitigation
Assessing irrigated crops’ adaptability under future climate: the interplay of water management and cultivars’ responses

Francesca De Lorenzi (1,*), Antonello Bonfante (1), Angelo Basile (1), Silvia Maria Alfieri (1), Eugenia Monaco (1), Massimo Menenti (2)

(1) Institute for Mediterranean Agricultural and Forest Systems - Italian National Research Council (ISAFoM-CNR), Ercolano (NA), Italy
(2) Department of Geoscience and Remote Sensing, Delft University of Technology, Delft, The Netherlands
(*) Corresponding author Email: francesca.delorenzi@cnr.it

Abstract:

The effect of climate evolution on the sustainability of irrigated agricultural systems will be site-specific depending on: (i) resource availability, (ii) crops’ water requirements, (iii) soil hydrological behavior and (iv) irrigation management strategies.

In an irrigated district of Southern Italy, for two field crops (maize and tomato), we have evaluated various irrigation scheduling options in different climate scenarios, and we have assessed the adaptability of many cultivars.

We have first estimated the yield response to water of several maize and tomato cultivars. Next, to identify options for adaptation, we have evaluated the compatibility of such responses with indicators of soil water availability, with different irrigation strategies, for a reference (current) and future climate. This compatibility assessment was done for each soil unit within the study area. The derived spatial and temporal variations of soil water regime and adaptability were studied.

Two climate scenarios were considered: reference (1961-90) and future (2021-2050) climate, the former from climatic statistics, and the latter from statistical downscaling of general circulation models (AOGCM). Climatic data consist of daily time series of maximum and minimum temperature, and daily rainfall on a grid with a spatial resolution of 35 km.

The work was carried out in the Destra Sele irrigation scheme (22,000 ha). Twenty-five soil units were identified and their hydrological properties were determined (measured or estimated from HYPRES pedo-transfer functions). Upper boundary conditions were derived from the two climate scenarios. Maize and tomato crops (in the rotations typical of the area) were considered.

A mechanistic model of water flow in the soil-plant-atmosphere system (SWAP) was used to describe the hydrological conditions in response to climate and irrigation. The model was calibrated and validated in the same area for many different crops. Crop-specific input data and model parameters were estimated on the basis of local experiments and of scientific literature and assumed to be generically representative of the species.

Simulations were performed for reference and future climate, and for different irrigation scheduling options. In all soil units, a set of irrigation scheduling volumes was applied: from full to no irrigation, through different levels of deficit irrigation. From simulation runs, indicators of soil water availability were calculated; moreover the marginal
increases of transpiration per unit of irrigation volume ($\Delta T/I$) were computed, in both climate scenarios. Indicators and marginal increases were used to evaluate crops’ adaptability to future climate.

To this purpose, for several maize hybrids and tomato cultivars, yield response functions to soil water availability were determined (data from scientific literature and experiments). Cultivars’ response functions were evaluated, in all soil units, against the indicators’ values, for irrigation levels with different $\Delta T/I$.

Less water intensive cultivars and irrigation volumes that optimize transpiration (and yield) could thus be identified in both climate scenarios, and irrigation management scenarios were determined taking into account soils’ hydrological properties, crop biodiversity, and efficient use of water resource.

The results have shown the spatial patterns of soil water regime, that were strongly influenced by soils’ characteristics. Moreover the case study has shown how, in the future climate scenario, with limited water resources, the intra-specific biodiversity will allow to maintain current crop production system.

*Keywords*: simulation models, deficit irrigation, water resource efficiency, maize, tomato
Improved wheat agricultural practices to cope with climate change effects in Jordan

Yahya Shakhatreh\(^{(1,\ast)}\), Pedro Carvalho\(^{(2)}\), John Foulkes\(^{(2)}\), Iyad Musallam\(^{(1)}\), Faddel Ismail\(^{(1)}\), Yahya Bani Khalaf\(^{(1)}\)

\(^{(1)}\) National Center for Agricultural Research and Extension (NCARE), P.O BOX 639-Baq'a' 19381 Jordan
\(^{(2)}\) The University of Nottingham, Plant and Crop Sciences Division, Sutton Bonington Campus, LE12 5RD, Loughborough, UK
\(^{\ast}\) Corresponding author Email: shakhatreh12@yahoo.com

Abstract:

Durum wheat (\textit{Triticum turgidum} L. var. durum) is one of the main field crops in the semi-arid region in Jordan. However, yields are low with an average of 1.2 t/ha. The main causes for low yields are low and unevenly distributed rainfall, poor soil fertility and the non-sustainable conventional agricultural practices. The lack of organic matter combined with intensive tillage has resulted in low organic matter content, destruction of soil structure and a decrease of infiltration and water storage capacity. Previous data showed a decrease of the amount of rainfall and a slight increase in temperatures, in agreement with the predicted scenarios for the Mediterranean region by the IPCC. Furthermore, a delay in the effective rainfall has been observed in recent years. The impact of climate change will adversely affect the cereal production in Jordan. Therefore, there is an urgent need to adapt the production systems to make a sustainable use of soil and water resources.

With the aim to increase grain yield and water use-efficiency under rainfed agriculture a field experiment was conducted at Maru agricultural station (Irbid, Jordan) in the 2012/13 growing season to investigate the performance of different wheat genotypes growing under zero and conventional tillage and three sowing dates. Detailed analysis of: phenology, canopy size (normalized difference vegetative index; NDVI), leaf chlorophyll content (SPAD) and leaf chlorophyll fluorescence, water use, yield and yield components was performed. The effects of the different agricultural practices investigated in this study on crop performance and their physiological basis are discussed.

Keywords: wheat, zero-tillage, sowing date, drought
Climate change and Mediterranean agriculture: (I) Impacts on wheat and tomato crop water and irrigation requirements

Sameh Saadi(1,*), Mladen Todorovic(1), Lazar Tanasijevic(1) and Luis Santos Pereira(2)

(1) CIHEAM – Mediterranean Agronomic Institute of Bari, Italy
(2) CEER, Instituto Superior de Agronomia, Universidade de Lisboa, Portugal
(*) Corresponding author Email: saadi_sameh@hotmail.fr

Abstract:

This work used the monthly climate data derived from the ENSEMBLES (EC-FP6-ENV) and WASSERMed projects (EC-FP7-ENV) and the Regional Circulation Model driven by the General Circulation Model ECHAM5 to represent two time periods: 1) present – year 2000, through 1991-2010 average, and ii) future – year 2050, through 2036-2065 average. The climate data, based on A1B SRES scenario, indicated an overall increase of air temperature from 0.84 to 2.31°C and an overall change of annual precipitation ranging from -408 to +143 mm in the Mediterranean area. As a consequence, the reference evapotranspiration (ET0) could increase in average over the region by 108 mm year\(^{-1}\) (7.2%). The greater increase of ET0 is foreseen for the western countries of the Mediterranean. Based only on temperature, the potentially cultivable area of winter wheat and tomato may increase in 2050 by 7 and 24%, respectively. New cultivable areas might be extended prevalently in the Northern Mediterranean countries. The average lengths of winter wheat and tomato growing season are likely to be shorter in 2050 by 15 and 12 days, respectively. Due to shorter growing season, the average crop ET over the whole region is expected to decrease by 5% for both winter wheat and tomato. Wheat ET would not change under rain-fed conditions. For tomato, an overall decrease of ET by 4 to 2% under mild to severe water stress may be expected. Net irrigation requirements (NIR) for irrigation with no water restrictions would decrease by 10 and 9% for winter wheat and tomato, respectively. Wheat NIR would decrease by 11 and 12% under mild and moderate deficit irrigation, while tomato NIR would decrease by 10, 11 and 13% under deficit irrigation corresponding to mild, moderate and severe water stress.

Keywords: Length of crop cycle, potentially cultivable area, crop evapotranspiration, irrigation requirements, deficit irrigation, A1B SRES.
Climate change and Mediterranean agriculture: (II) Impacts on wheat and tomato yields and water productivity

Sameh Saadi\(^{(1,*)}\), Mladen Todorovic\(^{(1)}\), and Luis Santos Pereira\(^{(2)}\)

\(^{(1)}\) CIHEAM – Mediterranean Agronomic Institute of Bari, Italy  
\(^{(2)}\) CEER, Instituto Superior de Agronomia, Universidade de Lisboa, Portugal  
\(^{(*)}\) Corresponding author Email: saadi_sameh@hotmail.fr

Abstract:

Climate data, derived from the ENSEMBLES (EC-FP6-ENV) and WASSERMed (EC-FP7-ENV) projects and the Regional Circulation Models, driven by the General Circulation Model ECHAM5, were used to represent: 1) the baseline conditions – year 2000, through 1991-2010 average, and ii) the future scenario – year 2050, through 2036-2065 average. As a whole, over the Mediterranean, a slight decrease of RYL is expected although an overall increase in potential yield could be in the future. The Northern part of the Mediterranean, except Turkey, would have a trend for decreased relative yield losses (RYL) of wheat while in the Southern and Middle East countries an inverse trend could be detected affecting especially the rainfed wheat due to an increased frequency of dry spells. Overall, tomato RYL would decrease in the future due to shortening of the growing cycle especially when the initial phases are kept unchanged. The adoption of deficit irrigation for a summer crop, as tomato, is predicted to generate large yield losses. The water productivity (WP) was estimated as the ratio between yield and crop evapotranspiration (WP\(_{ET}\)) and yield and net irrigation requirements (WP\(_{IRR}\)). An overall increase of WP is expected in the future due to, on one side, a probable greater production per hectare, induced mainly by the positive effects of CO\(_2\), and on the other, a shorter growing season and a decrease of ET and NIR for both studied crops. The impact of precipitation decrease would be more evident for the winter crops (winter wheat) because rainfall is scarce in spring-summer season and most crops (tomato) are already irrigated. Hence, in the Mediterranean basin, adopting supplemental irrigation for winter wheat, which growth season develops during the rainy period is feasible. However, for tomato, cropped out of the rainy season, every deficit strategy produces large yield losses.

Keywords: relative yield loss, crop evapotranspiration, net irrigation requirements, irrigation.
Assessing the adaptive capacity of durum wheat cultivars to future climate

Eugenia Monaco(1,*) (1), Angelo Basile(1), Francesca De Lorenzi(1), Roberto De Mascellis(1), Silvia Maria Alfieri(1) and Massimo Menenti (2)

(1) Institute for Mediterranean Agricultural and Forest Systems - Italian National Research Council (ISAFoM-CNR), Ercolano (NA), Italy
(2) Department of Geoscience and Remote Sensing, Delft University of Technology, Delft, The Netherlands
(*) Corresponding author Email: eugenia.monaco@isafom.cnr.it

Abstract:

The perspective of climate change requires an analysis of the adaptation possibilities of species currently cultivated. A powerful tool for adaptation is the relevant intra-specific biodiversity of crops. The knowledge, for different crop cultivars, of the responses to different environmental conditions (e.g. yield response functions to water regime) can be a tool to identify adaptation options to future climate. Moreover climate scenario needs to be downscaled to the spatial scale relevant to crop and farm management. Distributed models of crop response to environmental forcing might be used for this purpose, but severely constrained by the very scarce knowledge on variety-specific values of model parameters, thus limiting the potential exploitation of intra-specific biodiversity towards adaptation.

We have developed an approach towards this objective that relies on two complementary elements: A) database on climatic requirements of durum wheat varieties: the yield response functions to water availability were determined from scientific literature. These functions were applied to describe the behaviour of the cultivars with respect to the soil water availability; B) the simulation performed by the agro-hydrological model SWAP (soil-water-plant and atmosphere), to determine the future soil water regime at landscape scale.

The case-study presented here shows how the yield response of durum wheat cultivars to soil water availability can be defined by means of variety-specific threshold values of soil water (or evapotranspiration) deficit. The soil water regime calculated by the distributed model is compared with the threshold values to identify varieties compatible with expected climate. The operation is repeated for a set of realizations of each climate scenario. This analysis is performed in a distributed manner, i.e. using the time series for each model grid to assess possible variations in the extent and spatial distribution of cultivated area of durum wheat cultivars.

The selected study area is a hilly region of about 40,000 ha in Southern Italy (Fortore Beneventano, Campania Region), characterized by a complex geomorphology including clayey and marl flysch hills and highlands, narrow alluvial planes, and small sandstone relieves. Future climate scenarios in the area were generated within the Italian National Project AGROSCENARI. Climate scenarios at low spatial resolution generated with general circulation models (AOGCM) were down-scaled by means of a statistical model (Tomozeiu et al., 2007). The downscaled climate scenario includes 50
realizations of daily minimum, maximum temperature and precipitation data, on a regular grid with a spatial resolution of 35 km, for the 2021-2050 period. The down-scaled climate scenario was further refined by using the distributed model which describes the soil water regime in four soil systems units. Spatial pattern of soil water and evapotranspiration deficit was determined for the 50 realizations of the daily time series, taking into account the four soil systems, and was compared with threshold values to evaluate cultivars’ adaptation options to the foreseen future climate. The case study shows how, in the future climate scenario, the intra-specific variability will allow to maintain current crop production system.

The work was carried out within the Italian national project AGROSCENARI funded by the Ministry for Agricultural, Food and Forest Policies (MIPAAF, D.M. 8608/7303/2008)

**Keywords:** durum wheat, simulation models, climate change, soil water availability
Optimising irrigation practices of durum wheat and spring barley to cope with climate change effects in Jordan

Pedro Carvalho(1), John Foulkes(1), Yahya Shakhatreh(2, *), Iyad Musallam(2), Faddel Ismail(2), Yahya Bani Khalaf(2)

(1) The University of Nottingham, Plant and Crop Sciences Division, Sutton Bonington Campus, LE12 5RD, Loughborough, UK
(2) National Center for Agricultural Research and Extension (NCARE), P.O. BOX 639-Baq’a 19381 Jordan
(*) Corresponding author Email: shakhatreh12@yahoo.com

Abstract:

Durum wheat (Triticum turgidum L. var. durum) and spring barley (Hordeum vulgare L.) are the main cereal crops grown in the Mediterranean Basin, constituting 65% of the total arable area (FAO 2012). Spring barley is usually considered to be more drought tolerant than durum wheat (Cossani et al. 2007). Thus, barley is usually grown in the arid regions, while the more favourable semi-arid regions are reserved for wheat production (Ryan et al. 2008). In the Southern Mediterranean countries, yields on average for wheat and barley are low, 2.3 and 1.5 t ha\(^{-1}\), respectively (FAO 2012), mainly due to water limitations particularly during grain filling. Future climate scenarios by the IPCC for the region indicate a further decrease in water availability. In Jordan wheat and barley are mainly grown under rain-fed conditions. However in the future supplemental irrigation might be considered to increase yield and food-security in the region. The objective of this study was to investigate the water capture, water-use efficiency and growth and yield responses of durum wheat and spring barley to different irrigation treatments in Jordan.

In the 2012/13 growing season a field experiment comparing the responses of durum wheat and spring barley grown under rainfed and two supplemental irrigation treatments was conducted at Maru agricultural station (Irbid, Jordan). Measurements included: phenology, canopy size (normalized difference vegetative index; NDVI), leaf chlorophyll content (SPAD) and leaf chlorophyll fluorescence, water and N use, yield and yield components. The response of durum wheat and spring barley to the different irrigation treatments and their physiological basis are discussed.

Keywords: wheat, barley, drought, supplemental irrigation
Adapting to climate change: testing possible measures to stabilize wheat and barley yields in a Mediterranean environment

Marie Therese Abi Saab\(^{(1,*)}\), Rossella Albrizio\(^{(2)}\), Musa Nimah\(^{(3)}\), Pasquale Giorio\(^{(2)}\), Mohamed Houssemeddine Sellemi\(^{(2)}\), Suzi Rouphael\(^{(1)}\), Ihab Jomaa\(^{(1)}\), Randa Massaad\(^{(1)}\), Salim Fahed\(^{(1)}\), Rabih Kabalan\(^{(1)}\), Chafic Stephan\(^{(1)}\), Marica Abi Nader\(^{(3)}\)

\(^{(1)}\) Lebanese Agricultural Research Institute, P.O. Box 90-1965, Fanar, Lebanon
\(^{(2)}\) Istituto per i Sistemi Agricoli e Forestali del Mediterraneo, CNR-ISAFoM, Via Patacca 85, 80056, Ercolano (NA), Italy
\(^{(3)}\) Association of the Friends of Ibrahim Abdel Al, P.O.Box: 11/4981, Beirut, Lebanon
\(^{*}\) Corresponding author E-mail: mtabisaab@lari.gov.lb

Abstract:

Mediterranean agricultural systems are vulnerable to the climate. In addition, under the combined pressure of temperature increase and the drop in precipitations, cropping systems could suffer from yield variability inducing an increase of farmers’ income variability. In this context, we tested possible adaptation measures to climate change for wheat and barley agricultural systems grown under the semi-arid conditions of the Bekaa valley in Lebanon. Two experiments were conducted at Tal Amara Research Station of the Lebanese Agricultural Research Institute; in the first experiment, two varieties of wheat, Icarasha and Miki, were tested in combination with early sowing coupled with 50 mm amount of irrigation, spring supplemental irrigation and conservation tillage arranged in a split split plot design, while in the second experiment, two varieties of barley, Rihane 03 and Assi, were tested in combination with the same management practices. Besides yields, other agronomic data were collected throughout the growing season, and the crop water productivity defined as the ratio of yield over crop evapotranspiration was calculated. Collected data was analysed and presented to show the significant stability following these agricultural practices. Farmers in the region should seriously consider adopting such practices that could constitute possible adaptation measures to climate change, particularly if combined with promising varieties.

Keywords: Climate change, agricultural systems, early sowing, supplemental irrigation, conservation tillage
Prediction of climate change impacts on cotton yields in Greece under eight climatic models using the AquaCrop crop simulation model

Dimitrios Voloudakis(1,*), Garifalia Economou(1), Vasilios Kotoulas(1), Petros Vahamidis(1), Andreas Karamanos(1), John Kapsomenakis(2)

(1) Agricultural University of Athens, Laboratory of Agronomy, 75 Iera Odos str, 11855 Athens, Greece
(2) Research Centre for Atmospheric Physics and Climatology, Academy of Athens, 84 Solonos str, 10680 Athens, Greece
(*) Corresponding author E-mail: voloudakis.dim@aua.gr

Abstract:

The impact of climate change on cotton yields in seven main arable crop sites in Greece (Agrinio, Alexandroupolis, Arta, Karditsa, Mikra, Pyrgos, Yliki) was investigated. The FAO AquaCrop (v.4) water driven model was used as a crop development simulation tool under eight climatic models (HadRM3, C4I, REMO, ETHZ, CNRM, DMI, KNMI, SMHI) based on IPPC’s A1B Climate Change scenario. The mean values of the models ensemble for temperature and precipitation were +1.8˚C until 2050 and +4 ˚C until the end of the century. The respective values for precipitation were -11% and -24%. The research was applied over three periods, 1961-1990, 2021-2050 and 2071-2099. AquaCrop validation for yield, biomass and canopy cover in respect to field data obtained from experiments carried out in Karditsa (Central Greece) from 2005 to 2007 was satisfactory on the account of Model Efficiency (values between 0.74 and 0.84), Root Mean Square Error (0.08 to 0.38) and Index of Agreement (0.89 to 0.96). AquaCrop model was run using the Growing Degree Day mode in order to account better for the temperature variations. However, it gave erratic results for some specific climatic models (SMHI, KNMI, CNRM) in some years within the period 1961-1990. The predicted yields were highest in locations of western Greece (Agrinio, Arta, Pyrgos), whereas north-eastern Greece (Alexandroupolis) appeared to be less favoured by climate change. A tendency towards increasing yields by the end of the century was detected for the majority of the models. The efficiency of the eight models for yield predictions in the seven sites was assessed by means of a discriminant function analysis. On the account of their function coefficients over the seven sites, it was found that the models REMO, DMI and ETHZ explained consistently a great proportion of variation in the periods 1961-1990 and 2021-2050, whereas the models ETHZ and KNMI were more efficient in the period 2071-2099.

Keywords: AquaCrop, climate change, cotton, model classification, Greece
Impacts of climate change on olives crop evapotranspiration and irrigation water requirements in the Mediterranean region

Lazar Tanasijevic 1, Mladen Todorovic 1−*, Claudia Pizzigalli 2, Piero Lionello 3, Luis S. Pereira 4

1 CIHEAM, Mediterranean Agronomic Institute of Bari, Vie Ceglie 9, Valenzano (BA), Italy
2 SAIPEM S.p.A., Ocean Engineering Department, Fano (PU), Italy
3 CMCC, University of Salento, Lecce, Italy
4 CEER, Instituto Superior de Agronomia, Universidade de Lisboa, Portugal
*Corresponding author E-mail: mladen@iamb.it

Abstract:

The Mediterranean basin is the largest area around the world having specific climatic conditions suitable for the cultivation of olives, which have a great importance in most of Mediterranean countries. However, the Mediterranean region may be particularly affected by climate change, with warming expected to be larger than the global average and associated with reduction of precipitation, which interannual variability tends to increase. Such climate changes are expected to have extensive impacts on global ecosystem with olives naturally sensitive to climate variation, mainly phenological dates, crop growth and yield, crop water requirements, net irrigation requirements (NIR) and water availability. Climate data have been derived from the WASSERMed project (EC-FP7-ENV) elaborations and RCM simulations. Data refer to monthly values of A1B SRES scenario and a spatial resolution of 0.25° x 0.25° (latitude by longitude). The data used in the analysis represent two time periods: i) present, also called year 2000 (average values for the period 1991-2010), and ii) future, called year 2050 (average values for the period 2036-2065). Reference evapotranspiration, \( \text{ET}_o \), is going to increase due to climate change; a greater percentage increase of \( \text{ET}_o \) refers to the winter season but in absolute value higher increases are expected to be in summer. The occurrence of olives’ flowering is likely to be anticipated up to 15 days and irrigated olives’ and crop evapotranspiration is expected to increase in average of 3%. NIR may increase in average by 7%, however up to 150 mm in Southern Spain. Differently, actual ET of rainfed olives would decrease in most areas due to less water availability, thus making it not possible to keep rainfed olives in large areas where they are produced today.

Keywords: crop evapotranspiration, net irrigation requirements, rainfed olive’s cultivation, olive’s flowering dates, areas suitable for olive’s cultivation, phenological dates.
Adaptation to climate change of irrigation management of Peach tree cultivars

Silvia Maria Alfieri (1,*), Angelo Basile (1), Francesca De Lorenzi (1), Eugenia Monaco (1), Antonello Bonfante (1), Maria Riccardi (1), Daniele Missere (2), Claudio Buscaroli (2), Massimo Menenti (3)

(1) Institute for Mediterranean Agricultural and Forest Systems - Italian National Research Council (ISAFoM-CNR), Ercolano (NA), Italy
(2) Centro Ricerche Produzioni Vegetali, Cesena, Italy
(3) Department of Geoscience and Remote Sensing, Delft University of Technology, Delft, The Netherlands
(*Corresponding author E-mail: Silvia.alfieri@isafom.cnr.it

Abstract:

It is a common irrigation practice of fruit growers to fine-tune timing and amount of water gifts to achieve higher productivity and better quality. This requires different irrigation strategies during different phenological stages. Moreover, irrigation management should be adapted to different cultivars, besides weather and climate. Finally, after harvest, water gifts may be reduced to the minimum level required for plant survival. Adaptation to climate change adds an additional dimension to the challenge of designing and applying optimal irrigation scheduling.

This challenge can be met by a combination of experiments and modelling on the water balance of the soil plant atmosphere system. The objective of this paper is to evaluate the magnitude and significance of differences in the modelled soil water deficit (as a function of time) when taking into account the specific phenological cycle of each cultivar versus a generic assessment for each species.

We present the results of a case study on Peach cultivars in an area of the Po Valley where fruit crops are intensively grown (Imola). We evaluated for several Peach cultivars the soil water deficit and the irrigation requirement taking into account the shifting in phenological phases in response to air temperature. This analysis is performed taking into account the variability of soils.

A reference (1961-90) and future (2021-2050) climate were considered. Reference climate has been produced applying a spatial statistic approach on ground observations. Future climate scenario has been generated from statistical downscaling of general circulation models (AOGCM). The results consist of daily time series of maximum and minimum temperature, and daily rainfall on a 35km*35km grid. The grid node located near Ravenna is the most representative of the local climate within the study area.

The phenological development in reference and future climate is modeled using phase – specific thermal times and variety specific thermal requirements for peach cultivars. These requirements were estimated using phenological observations over several years in Emilia Romagna region and scientific literature. We calculated the dates of start and end of rest completion, flowering, fruit development and ripening stages, from late autumn through late summer.
Then, a mechanistic model of water flow in the soil-plant-atmosphere continuum was used to describe the hydrological conditions in each phenological phase in response to climate and irrigation. Crop-specific input data and model parameters were estimated on the basis of local experiments and of scientific literature and assumed to be generically representative of the specie. Soils hydrological properties of the study area were determined from HYPRES pedo-transfer functions. Upper boundary conditions were derived from the two climate scenarios. Statistics on time series of soil water deficit were compared with control numerical experiments where both inter-cultivars differences and the shifting of phenological stages were neglected.

**Keywords:** Peach cultivars, Irrigation, hydrological modelling, phenology, climate change
Farm adaptation strategies to cope with climate change in arid and semi-arid Mediterranean areas

Mladen Todorovic(1,*), Vito Buono(1)

(1) CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano (BA), Italy
(*) Corresponding author E-mail: mladen@iamb.it

Abstract:

This work aims to assess the effectiveness of farm adaptation strategies to cope with the impact of climatic change on irrigation requirements and crop yield, for five crops (wheat, tomato, potato, maize, olive) in five selected case-study areas (Italy, Greece, Egypt, Tunisia and Jordan). Present (2000) and future (2050) climate data refer to A1B SRES scenario as determined within the ENSEMBLES project. The estimation of crop evapotranspiration (ETc) and irrigation requirements (NIR) has been done according to the FAO-56 methodology (Allen et al., 1998). A linear growing-degree-days model has been used to estimate the changes in the cropping season duration under different thermal conditions. The estimation of yield and crop response to water has been modelled according to Rao et al. (1988), and site-specific crop water productivities (WP) have been chosen within the ranges suggested by FAO. Additionally, some ‘adjusted’ WP values have been used to consider the fertilizing effect of increasing CO2 levels under future climate (Raes et al., 2012). For the specific case of olive crop the monthly Kc-values have been determined as suggested by Orgaz et al. (2006), while yield-response-to-water function has been implemented according to Moriana et al. (2003). Then, a set of farm adaptation strategies has been tested: 1) a relatively wide interval of shifting of planting dates; 2) the use of late-maturing varieties (simulated by increasing the cycle duration of current ones 10%); 3) the application of different irrigation strategies (full, deficit, supplemental, rainfed). Results of simulations can be summarized as follows: a) the predicted temperature rise will determine a reduction in total crop cycle length and, as a consequence, in seasonal crop ETc and NIR; b) daily ETc is however predicted to increase determining a higher rate and frequency of irrigation; c) the main effect of the shortening of the growing period will be the corresponding yield reduction; d) however, yield is projected to increase provided that the expected fertilizing effect of increased CO2 concentration will occur, thus overcoming the negative effect of crop cycle shortening; e) in any case, yield reductions could be effectively countered by means of late maturing varieties, but with the important drawback of the increase of seasonal ETc and NIR; f) then, a proper combination of planting dates and irrigation strategies could be effective in ensuring acceptable yields without excessive increase in crop water requirements. Some important limitations to the concrete application of the selected adaptation strategies are reported

Key words: Climate change, agriculture, adaptation strategies, evapotranspiration, irrigation, yield
The dynamic change of water based on Three-dimensional model in climate change conditions for Hulun Lake in Inner Mongolia, China

Biao Sun\textsuperscript{(1,*)}, Changyou Li\textsuperscript{(1)}, Sheng Zhang\textsuperscript{(1)}, Keli Jia\textsuperscript{(1)}, Xiaohong Shi\textsuperscript{(1)}, Shengnan Zhao\textsuperscript{(1)}

\textsuperscript{(1)}Inner Mongolia Agricultural University, Hohhot, 010018, PR China
\textsuperscript{(*)}Corresponding author E-mail: sunbiao_label@yahoo.com.cn

Abstract:

Hulun Lake, a large lake located on the cold and arid Hulunbeir grassland in the Inner Mongolia Autonomous Region, is fifth largest in China and largest in the north of the country. In order to research the dynamic change of water for Hulun Lake nearly 45 years, made vectorization operation used DEM of Lake Bottom to generated TIN 3D model in Arc GIS. Analysis TIN model used 3D analysis tool, to determine the equations between Water Level and Surface Area, Volume, the correlation coefficient of equations is higher, in the future research can be use Water Levels to calculate Volume according to the equation\( y = 0.778x^2 - 824.9x + 218588.9 \) in Hulun Lake. 3D visualization operation for TIN model, shown shapes of lake surfaces for the different water levels. Analysis of water balance in long time series based TIN model and data of lake hydrological, results showed the supply water of Hulun Lake should exist the groundwater recharge in addition to the atmospheric precipitation and runoff. The main reasons of water level decline, lake surface shrink are continuous reduce for rainfall and river runoff in recent years, such as Kelulun River and Wuerxun River, the water decrease in river relate to human outlet in upstream addition to decreased rainfall. The climate change showed dry trend in Hulun Lake region in recent years, the synthesis affects of the climate change and human activities caused lake surface continuous shrink. According to the lake water balance analysis and theory of lake ecological water requirement, minimum supply water yearly is 950 million m\textsuperscript{3} to ensure the Hulun Lake cease shrinking, to prevent the further deterioration of ecological environment. As a result, the Hulun Lake protection is urgent and necessary, otherwise the deteriorating ecological phenomena and economic losses will be incalculable. According to the research result and current lake protection and management experience, this paper puts forward some countermeasures and suggestions for protect Hulun Lake: (1) supply lake use water diversion from other river, (2) strengthening the comprehensive management of lake basin, (3) establish a good management system, (4) take the scientific arguments for the scheduling of water resources, (5) to strengthen the public consciousness, the building public participation system.

Keywords: water change, three-dimensional model, lake surface shrink, climate change, Hulun Lake
Modeling Climate Change Impact on the Water Balance of a Coastal Watershed in Lebanon

Ivan Portoghese\textsuperscript{(1),\textsuperscript{*}}, Sagedah Saqallah\textsuperscript{(2)}, Michele Vurro\textsuperscript{(1)}, Talal Darwish\textsuperscript{(3)}, Amin Shaban\textsuperscript{(3)}, Roula Khadra\textsuperscript{(2)}

\textsuperscript{(1)} Consiglio Nazionale delle Ricerche, IRSA – UOS di Bari, viale F. De Blasio 5, 70132 Bari, Italy
\textsuperscript{(2)} CIHEAM, IAM-Bari, via Ceglie 9, 70010 Valenzano (BA), Italy
\textsuperscript{(3)} National Council for Scientific Research, Remote Sensing Center, P.O.Box 11-8281, Beirut, Lebanon
\textsuperscript{*Corresponding author E-mail: ivan.portoghese@cnr.it}

Abstract:

Water, a precious and valuable natural resource in the Middle East, is a limiting factor for its development. The possible climate alterations likely to impact the Region with increasing global air temperatures and changing in precipitation patterns would lead to a sensible modification of hydrological processes at regional and local scales. Analyzing the potential impacts of climatic changes is an important step toward adaptation and mitigation especially for countries with vulnerable water resources. The objective of this study is to develop basin scale climate change scenarios (CCS) for a coastal watershed in Lebanon, Nahr Ibrahim watershed (NIW), which is representative of the snow-melt dominated watersheds located in Mount Lebanon (the so called water tower of the Middle East). The regional climate model PRECIS (Providing Regional Climates for Impact Studies) developed by Hadley Centre of U.K. was adopted as a dynamic downscaling of a global climate model (GCM) thus providing spatially detailed projections and scenarios of future climate over the area of interest at a resolution of about 25x25 km. Daily simulations for precipitation (P), maximum and minimum temperature (Tmax, Tmin) from PRECIS were adopted to evaluate the impact of climate change on the water balance of the NIW by taking into account the time series for the recent past (1980-2000), the present (2001-2011), the near future (2011-2030) and the distant future (2080-2098) and comparing them with the available climate observations in order to assess the possible future variation in precipitation and temperature. The available stations’ observations were also used to derive monthly regressions between climate and topographic elevations to be adopted as a simple interpolation tool to estimate the spatial distribution of T and P in NIW. Changes in climate variables resulted significant for the near future only for T while in the distant future, both P and T showed respectively remarkable decrease and increase. These alterations will correspond to a decrease in snow-covered area and anticipated snow-melt thus altering the water balance of NIW both in terms of mean values and variability. To simulate the impacts on stream flow regimes, basin scale CCS were coupled with a conceptual water balance model, previously developed and calibrated. A consistent module of the model was developed to capture the space-time dynamics of the snow cover and snow-melt contribution. Such computations allowed to assess the possible climate change impacts on the hydrological signature of NIW which resulted
strongly influenced by a shorter snowy period and a consequent enhanced seasonality of the river flows. The results may be helpful in assessing the opportunity of a new artificial reservoir as a strategy for climate change adaptation by enabling the storage of winter and spring flows as well as the regulation of flood peaks.

**Keywords**: climate change impacts, water balance modelling, Mediterranean water resources
Climate Change Impact on Snow Dynamics of the Lebanese Mountain Chains

Amin Shaban¹,¹ and Talal Darwich¹

¹National Council for Scientific Research, Beirut, Lebanon
(¹Corresponding author E-mail: geoamin@gmail.com

Abstract:

There are tremendous aspects of water resources in Lebanon where the surface water are the most exploited. However, snow is still the most remarkable aspect and plays a major role in feeding groundwater, springs and rivers in Lebanon. This water resource has been ignored since long time and it was only considered as a touristic aspect. Nevertheless, the recently existed challenges on water supply in the region, notably the climate change makes it necessary to monitor the behavior and dynamics of snowpack on the mountainous regions of Lebanon. Therefore, several studies have been carried out in this respect, notably by the use of space observations on several time series basis. While, few concerns were on the physical characteristic and behavior of snow. This study, which is the first of its type in the region, includes two major investigation systems. These are: remotely sensed data analysis and direct investigation of snow samples in the field to measure the density, depth, crystal shape and size, as well as the melting patterns. Therefore, daily MODIS satellite images, with moderate spatial resolution, were analyzed for the last two decades to monitor the changing snow cover area, as well as to induce the accumulation and melting regime. Whereas, field investigation was applied to 275 sites on different altitudes, dates and terrain aspects. The measures were correlated mainly with different geomorphic aspects and mainly with the altitude, terrain characteristics, sun light exposure and slope. It aims, in a broad sense, to create different empirical relations between snow cover dynamic, snow materials characteristics and the physical setting. Thus, understanding these relations can be a helpful tool to induce the impact of climate change aspects on snowpack; in addition, it contributes for new inputs on water resource management approaches, notably in the view of changing climatic regimes.

Keywords: water recharge, stream, snowmelt, run-off, mount-Lebanon
Session 9
Drought/Flood risk management
Using drought indicators to support drought risk management in irrigated agriculture

Ana Paulo\(^{(1,2)*}\), Luís S. Pereira\(^{(1)}\)

\(^{(1)}\) CEER – Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Tapada da Ajuda, 1349-017 Lisbon, Portugal
\(^{(2)}\) Escola Superior Agrária de Santarém, Quinta do Galinheiro, S. Pedro, 2001-904 Santarém, Portugal
\(^{(*)}\) Corresponding author E-mail: ana.paulo@esa.ipsantarem.pt

Abstract:

Drought impacts in irrigated agriculture result from the reduction of cultivated areas combined with yield losses due to insufficient water availability for irrigation. Rainfed agriculture depends exclusively upon precipitation and is more vulnerable to drought. Irrigated crops depend upon water volumes stored during the rainy season and drought mitigation is more easily feasible. Monitoring tools such as drought indicators may contribute to timely adopt strategies to attenuate drought impacts, namely in irrigated agriculture.

Three irrigation districts of southern Portugal, Sorraia Valley and Caia in Alentejo, and Silves, Lagoa and Portimão, in Algarve, where irrigated agriculture depends mostly on surface water reservoirs, were selected for this study. The stored water in the reservoirs is an indicator of water availability and is commonly used as a reservoirs drought indicator. However, related information can be improved combining drought indices and water storage levels. Precipitation and evapotranspiration monthly time series for the period 1941-2006 were used to derive probabilistic drought indices, such as the Standardized Precipitation Index (SPI), and indices based on the soil water balance such as the Palmer Drought Severity Index, PDSI, or a modification of the PDSI for Mediterranean conditions, the MedPDSI. Four weather stations Portalegre, Mora, Elvas and Faro, located in the irrigated areas, were used. The SPI was computed with different time scales, 3, 6, 9 and 12 months. Relations between drought indices in winter and spring months and storage levels of the surface reservoirs were investigated. Correlations are statistically significant. Higher correlations are obtained in January showing that cumulated precipitation recorded until the end of January is determinant to water storage. In general SPI is better correlated with water stored volumes than PDSI or MedPDSI. The SPI in shorter time scales relates better with the water storage in smaller reservoirs thus reflecting a weaker inter-seasonal carryover capacity.

The identification of a drought initiation by December or January is very useful for the adoption of water management measures regarding the irrigation season, which usually begins in April. The time evolution of drought indices may anticipate drought on-set identification as verified in past drought periods. Records of annual water volumes used in irrigation were also analyzed in order to identify water management practices in drought years. This study can improve knowledge on drought severity evolution and its relation with water stored volumes and help adopting practices to diminish drought impacts on irrigated agriculture.

Keywords: drought indices, water storage, water use, irrigated agriculture, Portugal.
Streamflow Drought Index modelling through Standardized Precipitation Index assisted by service-oriented paradigm

Borislava Blagojević(1,*), Vladislava Mihailović(2), Milan Gocić(1), Slaviša Trajković(1)

(1) University of Niš, Faculty of Civil Engineering and Architecture, 18000 Niš, A. Medvedeva 14, Serbia
(2) University of Belgrade, Faculty of Forestry, 11000 Belgrade, Kneza Višeslava 1, Serbia
(*) Corresponding author E-mail: borislava.blagojevic@gaf.ni.ac.rs

Abstract:

The early drought warning is of a great importance for the management of water resources. In the sequence of drought processes, hydrologic drought occurs after meteorological drought. Service Oriented Architecture (SOA) can improve representing hydrological processes such as evapotranspiration, circulation of water in the atmosphere, plants, soil and unsaturated zone, as well as drought, by using independent Web services. To establish a relation between hydrological and meteorological drought (i.e. runoff and precipitation), we use the Standardized Precipitation Index (SPI), and the Streamflow Drought Index (SDI). The SPI and the SDI are the simplest drought indicators to obtain, in respect to data type and availability. The SPI is well known and widely used index which quantifies wet and dry periods in a given area. Similarly to the SPI, which is a probability index based only on precipitation, recently introduced SDI is calculated from long term runoff data. In this paper, we investigate relationship between SPI and SDI for 22 basins in Serbia. We use the Mann-Kendall test to investigate trends of SPI and SDI over time. In our study, SOA is the tool for requesting time series, sharing hydrological and meteorological data, estimating and monitoring SPI and SDI. The main goal of this paper is to study correlation between hydrologic and meteorological drought for application in Web portal for regional drought monitoring.

Keywords: Hydrologic drought, Meteorological drought, Standardized Precipitation Index, Streamflow Drought Index, Service Oriented Architecture.
Drought and climate variability impacts on Bulgarian agriculture: the case of rainfed maize

Z. Popova(1,7), M. Ivanova(1), D. Martins(2), L.S. Pereira(2), K. Doneva(1), V. Alexandrov(3), M. Kercheva(1)

(1) N.Poushkarov Institute of Soil Science, Agrotechnology and Plant Protection - Academy of Agriculture, 1080 Sofia, 7 Shosse Bankya Str., Bulgaria
(2) CEER-Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Tapada de Ajuda, 1349-017 Lisboa, Portugal
(3) National Institute of Meteorology and Hydrology – Bulgarian Academy of Sciences, 66 Tsarigradsko chaussee Blvd., 1784 Sofia, Bulgaria

(*) Corresponding author Email: zornitsa_popova@abv.bg

Abstract:

Climate change creates uncertainties for grain production and irrigation management in Bulgaria. To cope with this situation, the vulnerability to agricultural drought is studied using climate data trend tests, simulations with WINISAREG water balance model, and the standard precipitation index SPI for representative climate regions over the period 1951-2004. The model was previously validated for late and semi-early maize hybrids on soils of small, medium and large total available water (TAW) in various locations of Bulgaria. Regarding a Transitional Continental Climate in the Thrace region, significant trend for precipitation decrease were found for Plovdiv and Stara Zagora in June(-3.52 and -3.3 mm yr⁻¹). It is combined with a positive trend in maximum air temperature (0.024 °C yr⁻¹) in the country. Thus the Thracian Lowland, with a decrease in precipitation and SPI-indices and an increase in temperature is particularly affected in May, June and July. Simulation results relative to Plovdiv show that, for soils with large TAW (180 mm m⁻¹), net irrigation requirements (NIR) range 0-40 mm in wet years and 350-380 mm in dry years. In soils of small TAW (116 mm m⁻¹), NIR reach 440 mm in the very dry year. NIR in Sofia and Silistra (a Moderate Continental Climate) are about 100 mm smaller than in Plovdiv while in Sandanski (a Transitional Mediterranean Climate) they are 30-110 mm larger. Rainfed maize is associated with great yield variability in Bulgaria (29<Cv<72%). The most variable yields are found for Plovdiv and Sofia, while in Sandanski (a Transitional Mediterranean Climate) they are 30-110 mm larger. Rainfed maize is associated with great yield variability in Bulgaria (29<Cv<72%). The most variable yields are found for Sandanski and Plovdiv for soils with low TAW. Considering for Plovdiv and Sofia, an economical relative yield decrease (RYD) threshold of, respectively, 60 and 48% of the potential maize productivity results that 30 % of years are risky in Plovdiv, 20% in Sofia and 63% in Sandanski. Results for North Bulgaria show lower impacts, where only 10% of the years are risky in Pleven and Silistra. It is observed that risky years increase when TAW decreases. It was found that SPI2 for “July-Aug” is a good indicator of maize stress and vulnerability to drought. For South Bulgaria, economical losses are produced when "July-Aug" SPI2 < 0.2 in Sandanski, < -0.50 in Plovdiv and Stara Zagora and < -0.90 in Sofia. In North Bulgaria, the threshold “July-Aug” SPI2 ranges between -0.75 (Lom) and -1.5 (Pleven). The corresponding NIR thresholds were identified. The derived reliable relationships and specific thresholds of seasonal SPI2 “July-Aug”, under which soil moisture deficit leads to severe impact of drought on rainfed maize yield for the studied climate regions and soil groups, are representative of a wider area.
of South East Europe and are used for elaboration of drought vulnerability maps and identification of drought prone areas at regional and national level.

**Key words:** Climate uncertainties, Isareg model, Maize, Trend Test Analyses, Soil water availability, Net irrigation requirements, Rainfed maize, SPI drought index
Assessing drought cycles using a Fourier analysis

Elsa E. Moreira\(^{(1,*)}\), Diogo S. Martins\(^{(2)}\), João T. Mexia\(^{(1)}\), Luís S. Pereira\(^{(2)}\)

\(^{(1)}\) CMA - Center of Mathematics and Applications, Faculty of Sciences and Technology, Nova University of Lisbon, Campus Caparica, 2829-516 Caparica, Portugal,
\(^{(2)}\) CEER - Biosystems Engineering, Institute of Agronomy, Technical University of Lisbon, Tapada da Ajuda, 1349-017 Lisboa, Portugal
\(^{*}\)Corresonding author E-mail: efnm@fct.unl.pt

Abstract:

This study investigates the existence long/medium cycles in precipitation time series that could represent the return periods of severe and extreme droughts. The method used is the analysis of Fourier applied to the annual precipitation with aim of obtaining the most frequent cycles that compound the precipitation time series. Drought was quantified using the Standardized Precipitation Index (SPI) with a 12-month time scale and a clustering analysis on the SPI Principal Components loadings was performed in order to find regions where drought characteristics are similar. The discussion on results of the Fourier analysis is performed for the three clusters identified. The analysis shows that the most frequent cycles found refer to a period of 32.5 years correspondent long-term variability of droughts present in the three clusters and a medium period of 9.3 years with high presence in cluster 3.

Keywords: Precipitation cycles, Fourier decomposition, SPI, Cluster analysis
Analysis of Drought using Standardized Precipitation Index

Rajat Kumar Panda1(1,*), Nagarajan R.1

IIT Bombay, India

(*Corresponding author E-mail: pandarajatkumar@gmail.com ; rn@iitb.ac.in

Abstract:
Drought is a natural hazard resulting from the low precipitation. When it extends for a longer period of time then it disturbs severely the socio-economic condition of a country. In that condition it is essential to plan out in advance for a sustainable water resource management. In this paper, precipitation (climatic variable) devised standardized precipitation Index (SPI) is used to analyze the drought intensity in the Ghataprabha River of south Peninsular India. The SPI is used considering 11 rain-gauge stations which are uniformly disseminated throughout the basin. It was found that there is a great variation in the drought severity in different parts of the basin. It is suggested that the Severity of drought in different parts will seek the attention while designing the optimum water allocation schemes.

Keywords: Ghataprabha, SPI, Drought, Precipitation
Studies on runoff and erosion rates in Eastern Romania

Nelu Popa(†), Dumitru Nistor, Eugen Filiche, Gabriel Petrovici

Research and Development Centre for Soil Erosion Control Perieni, Vaslui County, Romania
(†) Corresponding author E-mail: nelu_c_popa@yahoo.com

Abstract:

The paper presents experimental results reported for a period of 28 years, during 1985-2012, on runoff and erosion processes, measured on some runoff plots. The study area is located on the left hillside of the Upper Tarnii Valley from Tutova Rolling Hills, Eastern Romania where the soil is represented by a cambic chernozem, moderately eroded, with a 12% slope. The climate is temperate – continental of transition with excessive nuances where rainy periods alternate with severe drought periods. From the total of eight plots, six of them are 100m² (25×4m with 1 m border areas between them) and the other two are 150m² (37.5×4m). Six plots were cultivated by conventional tillage with different crops as follows: corn, beans, soybeans, winter wheat and bromegrass. Two check plots of 100 and 150m² were maintained like black fallow, always free of weeds. Runoff collection from each plot was made in three calibrated tanks disposed in cascade and after each event, the tanks were emptied and water and sediments were collected and analyzed. In addition, unconventional methods like Cs-137 and Be-7 techniques to determine erosion and sedimentation rates have been used. The intensity of erosion processes has been marked by some historical rainstorm events that have exceeded the value of 80 mm, in an area where the yearly average of precipitation is 492 mm. Significant interactions and feedbacks were found to occur between soil characteristics and vegetation, which influenced both runoff and erosion responses. Monitoring allowed more direct linkages to be made between management practices and their impacts on runoff and soil erosion, thereby enabling land owners to identify problems and take appropriate preventive measures to improve their management practices and even to diminish the risk of drought/flood.

Keywords: runoff, soil erosion
Session 10
Socio-economic aspects of land and water management
Hydro-economic modelling to assess climate changes
impact on agriculture water management
in a semi-arid region
1

1*

2

D. D’Agostino , A . Scardigno , D. El Chami , N. Lamaddalena

1

1

Department of Land and Water Resources Management - International Center for
Advanced Mediterranean Agronomic Studies (CIHEAM-IAM.B).
2
Bedfordshire MK43 0AL,
*Corresponding author Email: scardigno@iamb.it

Abstract:
An integrated hydro-economic modelling tool – applied to the Apulia region (Southern
Italy) – is proposed to define, at regional scale, the water balance components and the
water use in the agricultural sector. The hydrological model allowed to assess the
spatial and temporal variation of crop irrigation requirements and the water availability,
expressed in terms of surface runoff and groundwater recharge, while the integration
with the economic model allowed simulating the real farmers’ decision process in
response to any changes both in the constraints and in the boundary conditions. The
proposed tool provides a comprehensive information framework including: water
balance components, crops irrigation requirements, farmers choices in terms of land
use and irrigation techniques, economic results (costs and incomes), environmental
impacts. Climate, land cover and soil datasets have been implemented as thematic
maps into a GIS based model, and integrated with the main economic parameters at
farm and crop level. With the aim of assessing the variability of water balance
components, as crucial information to face with water resources management and
planning issues in semi-arid area and to achieve a more sustainable balance between
water demand and water availability, future scenarios of climate change have been
used to simulate their impacts on water balance.
According to the obtained results water availability, both in terms of groundwater
recharge and surface runoff, appears to be reduced all over the region in the future
scenario of climate change. The results also showed farmers’ strategy to adapt to
future changes by reducing the irrigated surface and shifting toward less water
intensive techniques. Further, there is an effect of crop substitution and dangerously
there is a serious phenomenon of land abandonment. Notwithstanding the complex
farm strategies adopted, farm income is seriously affected by future climate conditions
and the overall sustainability of the agricultural systems is put in question.
Keywords: hydro-economic model; agriculture water management; climate change;
semi-arid region

199


The objective of the study was to investigate how farmers could sustain an economically viable agricultural production on salt affected areas of Al-Musayyeb area in Central Iraq. It aims to assess the impacts of salinity on crop productivity, resource use and profitability under different soil salinity levels and to identify the socioeconomic factors that influence the salinity control efforts taken by individual farmers. Earlier research could not provide the causal relationship between soil salinity and the loss of crop production, resource use and allocative (cost) efficiency (AE) and income. In addition, salinity control efforts taken by farmers are not related to their socio-economic conditions.

A stratified random sample of 220 households were interviewed based on severity of salinity indicators. The scores and determinants of the AE were identified and factors that influence the salinity control efforts taken by individual farmers were determined using stochastic production frontier approach and the tobit model.

Empirical findings show that the estimated AE of the farms in the salinity-affected areas varied widely from 20 to 80%, with a mean value of 52%. This suggests that the average farmer needs a cost saving of 48% to attain the status of the most allocatively efficient farmer. However, in the salinity-free area, the predicted AE indices varied from 30 to 90% with a mean of 65%. This implies that improving the AE efficiency of these farms would help farmers to reduce their costs by about 35% of the technically efficient cost of production without reducing output. An analysis of the main determinants of the level of AE suggests that this is positively affected by the farmer's education level, family labor force and his off-farm income.

The average total factor productivity (TFP) of inputs has been estimated at 2.31% and 2.71%, for the farms in the salinity-affected areas and farms in the salinity-free areas, respectively. These indices are considered very low and they reflects the low level of income and the poor standard of living of these farmers. In addition, as TFP in farm is the inverse of the average variable cost on such farm, a decrease of 1% in the average variable cost in Al-Musayyeb salinity-affected and salinity-free farms would increase the TFP for only 2.31 and 2.71%, respectively. This implies mismanagement on the use of production resources. The empirical findings suggest that the contribution of the family
labor to the total labor requirements of the farm, off farm income and the land tenure play an important role in the increase of TFP.

The assessment of the profitability between farmers in soil salinity-affected and salinity-free areas was also conducted using the production function decomposition analysis. The estimated model accounts for more than 54% percent of the difference in gross margin between salinity-free and salinity-affected areas. The problem of salinity accounted for 41.76%. This value indicates that with the same level of resource use, compared to salinity-free area, gross margin would decline by 41.76% in soil-affected areas of Al-Musayyeb. However, about 13% percent of the gross margin difference could be attributed to change in input use in the salinity-affected areas.

Key-words: Allocative efficiency, profitability, living with salinity, GIS, Iraq.
The role of traditional irrigation canals in a long term environmental perspective. 
A case study in southern France: The Durance basin

Aspe Chantal (1,*), Jacqué Marie (2)

(1) Aix-Marseille University, IMBE, Marseilles, France
(2) Aix-Marseille University, LPED, Marseilles, France
(*)Corresponding author E-mail: chantal.aspe@univ-amu.fr

Abstract:

The agricultural sector is often considered as the major water consumer. That's why politics encourage saving irrigation water in all European countries. The adverse effects of this directive are in danger of causing the disappearance of traditional irrigation canals, because progressively the farmers have to develop drip irrigation or overhead irrigation. Therefore, we are defend that the traditional irrigation canals have to be reconsidered. Canals are not only constructing water infrastructure but also a product of a cultural and social water's relationship in Mediterranean area. In this way, canals form a complex system which is the result of ecological, economical and social dynamics.

The interest and originality of our sociological and environmental approach in Provence (and especially about Durance basin) is to indicate how the very dense territorial network of gravity-fed canals might be useful in water management and sharing considered in a long term perspective. In a warming climate through Mediterranean area these hydraulic structures would be an important managing tool water shortage or flood risk. Furthermore, our results underline the positive environmental functions fulfilled by these historical and anthropogenic constructions. They contribute to recharging the aquifer and they also provide valuable environmental goods and services (run-off regulation, biodiversity, landscape, recreation, etc.). In the same time, several local actors highlight their role of intangible cultural heritage in economic and social development.

The focus of our discussion will be about the conception of “water saving” which is not the same thing if we consider quantitative or qualitative approach. It’s necessary to question so: “economizing for what use?” In a quantitative way, canals are considered as water transport and distribution infrastructures but not as a complex system which provides local social and ecological services. In a qualitative way, the key issue is how to deal with the traditional functions and environmental services offered by canals. However today the responsibility for maintenance lies with the ASA (Authorized Syndical Association) and will depend on sufficient budgetary allocations by the owners of land. But it’s not sufficient to maintain canal structures including all the services and their key role in a sustainable development perspective. In southern France, a new form of governance had been promoted, called “Canals contract”, whose objective is to ensure the hydraulic system formed by canals and also a collective management organisation. The main purpose of this local democratic and concerted effort is to establish new modalities about water management. Finally we will question the new perspectives in examining their efficiency and their limits.

Keywords: Irrigation canals, environmental services, southern France, governance
The Criticality of Integrating Local Agro-Economic Institutions into Paradigms for LDC Poverty Reduction in the Anthropocene

Michael Davidson(1,*)

(1) Claremont Graduate University, Claremont, California, United States
(*) michaeldavidson24@gmail.com

Abstract:

Agricultural management interlinks the two most critical issues for human and ecological sustainability in the Anthropocene for the next two generations: providing food for impending population growth to reduce poverty and undernourishment to the 2050 Millennium Development Goal targets; and, managing for eco-system resilience in the context of global environmental change. In order to feed the increased population in 2050, global agricultural production will need to increase by 70% and in the Least Developed Countries (LDCs) agricultural production will have to increase by 100% (DuBois, Chen, Kanamaru, & Seeberg-Elverfeldt, 2012). The degree to which food demands are met, poverty and undernourishment significantly reduced and a 'safe space for human development' (Rockstrom, Lannerstad, & Falkenmark, 2006) created, depends upon the integration of the institutions of agriculture and irrigation into a holistic, conceptual framework that is implementable, adaptable, science-based, and operational at multiple scales in polycentric societies.

This paper examines the variety of agro-economic institutions in LDCs that are necessary to ensure increased agricultural productivity within the context of global environmental change and finds evidence that a critical gap exists in current institutions and policy and program interventions for agricultural development. The World Bank's International Development Assistance (IDA) program, the International Finance Corporation Poverty Reduction Strategy Program (PRSP), other, agricultural and development NGOs, Water User Associations and Extension Services all fail to integrate the critical, local agro-economic institution in all developed and developing agricultural communities: the irrigation dealer or distributor (dealer) network. The dealer network performs the irreplaceable role of the local strategic, economic and educational link between the irrigation and agricultural implement manufacturers and the smallholder and agribusiness communities. The criticality of the dealer/smallholder relationship in the supply value chain is inextricably and interdependently linked to the profitability and growth of the smallholder. All components of irrigation systems break down and require ongoing repair and replacement. Pumps require re-build kits, diaphragms in control valves require replacement, drip emitters clog and require chemicals for cleaning and systems underperform because they are not properly designed and/or installed.

2 The current geological epoch in which human actions have become the main driver of global environmental change (Steffen, Grinevald, Crutzen, & McNeill, 2011)
This paper captures and unpacks four models for the agricultural/irrigation dealer institution that vary in ownership but are commonly characterized by the primacy of formal institutional rules that create critical co-dependent relationships between manufacturers and dealers and between dealers and grower by linking the profit centers of all three entities together. This is a seminal study that analyzes the dealer as the principal agent in irrigation development. This paper explicates the disconnect between the institutions of agriculture and irrigation and the scholarly pursuit of sustainable water management and contributes to the wider discussion of the integration of agro-economic institutions into water research.

**Keywords:** Irrigation dealers, Sustainable agriculture, Global environmental change
Session 11
Policies, governance and institutional development
The EU-funded Sustainable Water Integrated Management Programme and its Support Mechanism: taking stock of the project

SWIM-SM Technical Team (info@swim-sm.eu)

LDK Consultants, Engineers and Planners S.A – SWIM-SM Project Director
(stavros@ldk.gr)
Global Water Partnership - Mediterranean (GWP-MED) - SWIM-SM Technical Director
(secretariat@gwp-med.org)

Abstract:

SWIM-Support Mechanism (SWIM-SM, 2010-2014) is the component of the EU-funded SWIM Programme that aims at providing targeted technical assistance to Partner Countries (PCs) Algeria, Egypt, Israel, Jordan, Libya, Morocco, Palestine, Syria and Tunisia (in May 2011, the European Union decided to suspend all cooperation with Syrian authorities) for the sustainable management of water resources through six types of interventions (each one under a Work Package) and activities structured and implemented around four Thematic Pillars that have been identified by the PCs as prominent issues of concern for their water sector. The focus is on “soft” interventions supporting policy reforms, governance, efficiency, fiscal and environmental sustainability, and climate change adaptation and mitigation.

The project’s work methodology consists of carrying out in-depth assessments on the identified priority issues that are subsequently verified by National and Regional experts and then serve as the basis for capacity building and drive future activities. Throughout the work, emphasis is placed on the identification and selection of best practices and success stories so as to showcase them and explore their potential replication. Moreover, synergies with relevant on-going initiatives and projects are being effectively sought and result in pooling of resources and joint implementation with maximum impacts. A strong communication component, supporting also the visibility of the five Demonstration Projects, promotes SWIM as a leading regional water Programme.

Some of the SWIM-SM achievements, under its Thematic Pillars, as relevant to the Conference, include: Non Conventional Water Resources: Identification and exposure of PCs to innovative/best available technologies for Wastewater Treatment, reuse in agriculture and groundwater recharge; Documentation of successful interventions concerning increased efficiency and effectiveness of wastewater reuse; Recommendations for advancing missing priority elements of the National Wastewater Strategies; Awareness raising for farmers on the safe reuse of treated wastewater in agriculture; Water infrastructure financing and potential partnership with the private sector; Economic Valuation of Water Pollution and Abatement Interventions: Monetary valuation of major river degradation in selected basins and suggestion of cost-effective remediation actions and; National consultations to validate and discuss the above studies; No-regret Actions for the Adaptation of the Water Sector to Climate Change: Guidelines on how to mainstream no-regret adaptation measures into IWRM plans and; Capacity development on precautionary measures for adapting the water sector to potential CC impacts; Water Governance at
the Local Level focusing on Water Users’ Associations (WUAs): Assessment of the status of WUAs & its validation through a regional Expert Group Meeting; Training on WUAs operationalisation; Information of PCs on the tools to ensure effective formulation of Participatory Irrigation Management/Irrigation Management Transfer Process (PIM/IMT) and the establishment of viable WUAs; Development of a Regional Monitoring & Evaluation (M&E) system for PIM/IMT. Indicative horizontal activities cutting across pillars/work packages include: Regional review of National Water Plans and Strategies and its validation through a regional workshop; Training of government officials on the preparation of water plans/strategies; Training on the inter-linkages between integrated water resources management (IWRM) and integrated coastal zone management (ICZM) and; capacity development of prosecutors and investigators to enforce water and environmental legislations.

**Keywords:** water management, IWRM, wastewater treatment, climate change adaptation, water governance, water users associations, economic valuation of water pollution
Connecting science with policy and innovation in order to improve water management in Europe

Gaëlle Nion 1*, Natacha Amorsi 1, Beatriz Medina 2, Darla Nickel 3, Ulf Stein 3, Johanna von Toggenburg 3, Andrea Goltara 4, Marta Borucka 5, Silviu Lacatusu 6, Terry Simms 7

1 Office International de l’Eau – France,
2 AMPHOS21 – Spain,
3 ECOLOGIC Institute – Germany,
4 CIRF – Italy,
5 GFW – Poland,
6 CFPPDA – Romania,
7 ESKTN – United-Kingdom,
*Corresponding author Email: g.nion@oieau.fr

Abstract:

Funding research is a fundamental aspect of the EU Directives set up. However, the implementation of these Directives requires a fast and efficient knowledge transfer to address water resources key issues. It currently takes around 10 years between research results production and the final knowledge transfer. This means that research commissioned today will impact water management practices within about 10 years, far after the next milestones of the Water Framework Directive. To avoid this gap, the WaterDiss2.0 project, managed by the Office International de l’Eau (OIEau), aims at creating a new service for research output uptake, an intermediate step between research producers and research “End users”. Under the banner of the Science-Policy Interface, the OIEau and the WaterDiss2.0 project supports dissemination and innovation processes and helps key stakeholders to improve innovative processes and methodologies in water management in a quicker way.

Taking this 10 years gap into account, WaterDiss2.0 consortium has identified that: a) Bridging the Science Policy Interface is one of the most urgent issues on the political agenda; b) Communicating with a clear message isn’t an easy task and requires specific communication skills; c) Successful dissemination depends on multiple factors; it requires: i) a carefully planned dissemination concept and strategy; ii) Sufficient time and resources; iii) Support from professional knowledge brokers.

Relying on a knowledge broker professional team, the WaterDiss2.0 project and the Office International de l’Eau (OIEau) offer service and support to research teams in terms of research results dissemination and uptake. These skills tested and developed in the framework of several European projects leads, among other tools, to the development of the Individual Dissemination Strategy (IDS) and of the European Water Community (EWC). These are two of the operational knowledge brokerage tools tested during 3 years.

The IDS (Individual Dissemination Strategy), an analysing tool, allows recommendation drafting for ensuring the uptake of research outputs. The goal is to define how to match research outputs with the target audiences and their specific needs and the
**contents, media, formats**, and languages to develop for a better dissemination. The goal is to define a strategy on “How to get the water research outcomes into the hands (and minds) of those target audiences?”

*The European Water Community, a communicating tool,* is a collaborative platform focused on European Water issues. The European water community is dedicated to researchers to allow them to promote their research results thus ensuring they reach operational status and to all water stakeholders as end users of research outputs. The objectives of this platform are to i) allow water stakeholders to exchange and discuss on water related issues; ii) store water related documents; and iii) be a portal allowing access to water research outputs directly and not to the projects themselves. It guarantees the operational level of the information available.

The European Water Community is a vector of communication between research producers and end-users.

Following a strong investment in Science Policy Interface actions, numerous dissemination events, the drafting of dissemination strategies and the creation of the European Water Community, the WaterDiss2.0 consortium drafted some recommendations in order to improve Science Policy Interface methods and support the uptake of the European Water Research. These recommendations apply to both SPI conceptual and operational aspects. They are meat for all European research stakeholders, producers and users.

**Key words:** knowledge brokerage, science policy interface, research uptake, innovation, water research, European water community
MEDSPRING: an example of open dialogue between research, civil society and policy makers

Gaetano Ladisa\(^{(1,\ast)}\), Marinella Giannelli\(^{(1)}\), Claudio Bogliotti\(^{(1)}\)

\(^{(1)}\) International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano, Bari, Italy
\(^{\ast}\) Corresponding author E-mail: ladisa@iamb.it

Abstract:

In the industrial era, innovation has been driven by technological processes. Differently from the past, today the drivers of innovation are embedded in society actual needs. For this reason, research is increasingly challenged by new actors and business models to enable the use of innovation with end users as co-owners. Therefore, issues like water scarcity, food security and renewable energy cannot be addressed only through new technological and organizational processes, but also in new forms of participation of individuals and organizations as well as of interaction among research, civil society and policy makers. This is the new key to enhance social innovation, which is in turn the base for sustainable, smart and inclusive growth. Thus, social innovation is necessary to improve living conditions, create employment, develop capabilities and promote participation. Participatory research, based on social dialogue could become a new paradigm for research and innovation within cooperation initiatives to the design effective policies. MedSpring is an Euro-Mediterranean dialogue gateway on research and innovation, funded by the European Commission in the frame of FP7 (www.medspring.eu). Among others, one of the activities – most interesting from the scientific and methodological point of view – is the implementation of a web-based dialogue platform (Euro-Mediterranean “Agora” – www.agora.medspring.eu). The Agora aims at strengthening and structuring the participation of civil society and web communities in the process of knowledge sharing, making recommendations, interacting with researchers and domain experts (like the Med-Spring Euro-Mediterranean Expert Group - EMEG) and developing new paradigms for research and innovation within major topics like water, food and energy. This process is enhanced by the linkage of civil society inputs, channeled through the Agora, with decision making institutions (e.g. ministries, national research centers). This allows the creation of long-term participative synergies involving all the actors of research and innovation.

Keywords: policy, research and innovation, public participation, water, food, energy, Mediterranean cooperation
Rural Water Access and Management Approaches in Southern Africa: Lessons from Namibia and South Africa

Selma Karuaihe1,*, Charles Nhachena1, Alfons Mosimane2, Omu Kakujaha-Matundu3

1 HSRC, 134 Pretorius Street, Pretoria 0001, South Africa.
2 Multi-Disciplinary Research Centre of the University of Namibia. Mandume Ndemufayo Street, Pionierspark, Windhoek, Namibia.
3 Faculty of Economics and Management Sciences at the University of Namibia, Mandume Ndemufayo Street, Pionierspark, Windhoek, Namibia.
*Corresponding author Email: skaruahei@hsrc.ac.za or karuaiheselma@yahoo.com

Abstract:

Water scarcity is a major problem for Namibia and South Africa as both countries are classified as “water stressed”, based on their per capita water availability, which is below the threshold of 1000-1666 m$^3$/person/year. While water scarcity remains the main challenge for economic development and sustainable livelihoods in both countries, affordability of basic services like water becomes another constraint, particularly for rural households who have to access water through various methods of payment, either in terms of distance or in monetary terms.

The Human Sciences Research Council (HSRC) based in South Africa and the University of Namibia (UNAM), are planning to conduct a joint study that investigate the different modes of rural water access and management approaches by the various communities in both countries respectively. The main objective of the study is to determine and analyse the respective communities’ capacity to use and manage the scarce water resources efficiently, and to see if there is room for pro-poor interventions including the integration of water management priorities in water policy. Further, there is a need to investigate and understand issues of water access, use and management and their potential to address poverty through consumption or other productive activities for agricultural and/or other business purposes for poverty reduction, growth and socio-economic development.

Researchers from both institutions will use data on rural water access and management, either through survey or through available sources at the relevant government offices responsible for water provision and/or management. The aim is to inform and guide the two country governments on the potential benefits that could arise from efficient water use and management in rural areas, or potential costs associated with the current systems of supply oriented water provision. The study could also show the necessary interventions to capacitate the communities and the relevant institutions in rural water provision. Lessons from the study can be extended to other parts of both countries, and also to other semi-arid countries within the Southern African Development Community (SADC) region as part of future research, depending on funding availability.

Water provision in both countries have traditionally relied on supply-side sources, and the potential for expansion is becoming dim, making efforts towards demand
management approaches more feasible. Preliminary findings show that community based management (CBM) systems of water points may be good, in terms of ownership and self-reliance based on institutional arrangements at community level. However, the CBM system involves some forms of payment for water access, and affordability has become a main challenge, to an extent that some governments are considering the re-introduction of water subsidies for poor rural communities in the near future.

The proposed research directly contributes to improving the scientific and technical knowledge on rural water management in general through collaborative research, and capacity building between UNAM and the HSRC. At the local level, rural access, management and utilisation of scarce water resources is constrained by capacity and other challenges. The proposed study will shed light on those potential constraints in order to guide future policy initiatives.

**Keywords**: water, scarcity, rural, management, access
Evolution of irrigation quality after the assistance for farmers: The experience of the advisory service for irrigators - SAI in “Baixo Acaraù” irrigation district

Sílvio C. R. Vieira Lima¹, José A. Frizzone², Richard L. Snyder³, Luciano Mateos⁴

¹INOVAGRI Institute, Rua João Carvalho, 800/1302, Fortaleza, CE, 60140-140, Brazil
²ESALQ/University of São Paulo, Av. Pádua Dias, 11, 13418-900. Piracicaba-SP, Brazil
³University of California, 223, Hoagland Hall One Shields Avenue, Davis, CA – 95616, United States
⁴IAS/CSIC, Campus Alameda del Obispo, Apartado 4084. 14080 – Córdoba, Spain

(⁎) Corresponding author Email: silviocarlos@inovagri.org.br

Abstract:

The irrigator must know how to irrigate and he needs to receive appropriate information. In Brazil, a pioneer project has been developed in Baixo Acaraú Irrigation District (DIBAU), Ceará State. It is the Advisory Service for Irrigators (SAI Project). The goal of the project is to transfer information about irrigation to the farmers. After registration is completed, an evaluation is applied on the farm and together with the weather stations database, a software performs the calculations of the irrigation time (IT). That information and others such as: evapotranspiration, water, energy, market, meetings are sent daily, by the web system by e-mail, SMS, and a farmer site on the internet. This way, the farmer knows “when, how much and how to irrigate”.

The aim of this study was to analyze the irrigation quality of the farmer from DIBAU advised by SAI. It was evaluated 44 farmers about water emission uniformity from drip and micro-sprinklers irrigation systems installed on that District, monthly, along two seasons of irrigation. The first results of field emission uniformity (EU) from DIBAU were initially shown by Santos Neto et al. (2011) that found some farms with low EU. After this time, a lot of evaluations of irrigations systems were done monthly by two years (2011-2012).

In that research were found initial values of uniformity of 61.6% at the beginning of the irrigation season and in the subsequent evaluations, following the recommendations of the technicians about the necessity of corrections into the systems, values reached up to 87.5% of uniformity.

These results show us that the low EU is always obtained at the beginning of irrigation season and it can be explained by combinations of factors. First: all systems had a few or no maintenance/operation over the past four months with lack of regulation and cleaning. Second: this stationary period incurs no orientation about the operation of the system by SAI Project, which will result initially in a low yield of the operator when this person starts his work.

As after the initial period of operation and advising, the EU average increases and keeps growing constantly, we can conceptualize an evolution of the irrigation quality at DIBAU.

We have concluded that SAI Project should be used as an important tool for water management in irrigated areas and the training for the farmers is very important for
good irrigation quality. Moreover, we think this research needs to include other criteria and components for better definition of this term “irrigation quality”. So, a new package of assessment, in 2013, at the same plots, is very important.

**Keywords:** Water Management; Evaluation; Irrigation Efficiency
Abstract:

During recent years, the Brazilian government has carried out several improvements in irrigated agriculture, such as investments in new hydraulic facilities and rehabilitation of older systems. In addition, several decision support systems tools are being developed and many are focused on in carrying out an efficient use of water and energy resources. These activities are really important since water scarcity, along with an increasing trend in production costs, makes it necessary to develop new management models for guaranteeing sustainable development in irrigated areas.

One of these tools is the Irrigation Advisory Service (IAS), combined with the use of performance indicators and energy audits in irrigated areas. These tools provide important information for improving water and energy management, together with other production costs.

The aim of this paper is to present the results of the IAS activities in the “Baixo Acaraù” irrigated area, located in the northeast of Brazil (Ceará), during the 2011 and 2012 irrigation seasons. Moreover, the results from the estimation of several performance indicators and from energy audit carried out during 2012 irrigation season are shown, as a complementary activity developed by the IAS.

The “Baixo Acaraù” irrigation district has approximately 8335 ha, being supplied by the Acaraù river which is the main source of water. Drip irrigation system is the prevalent irrigation application method. Coconut, banana, orange fruit, guava and papaya are the most representative crops. Several performance indicators developed by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) and other researchers have been applied.

The preliminary results show a high interest on the use of these tools and indicators by the district staff and farmers belonging to the irrigation area. During the first irrigation season (2011), a total of 203 plots were advised through the IAS program, which represented, approximately, 60% of the total plots in production. During the 2012 irrigation season, the number of advised plots increased, reaching 98% of the total under production.
The total number of irrigation system evaluations conducted was 38 in 2011, increasing to 138 for the 2012 irrigation season. These evaluations showed deficiencies in the performance of some irrigation systems, with some cases having application efficiencies lower than 70%.

During the 2012 irrigation season, some problems related to maintenance of equipment were noted, resulting in mal-functioning pumps. The values obtained through the energy audits showed pump efficiencies close to 40% for most of pumps analyzed. Due to these results, it will be really important to carry out maintenance activities before future irrigation seasons.

The results showed that the combined use of performance indicators and energy audits might be a useful tool for evaluating activities carried out by the Irrigation Advisory Service in the future.

**Keywords:** Irrigable area, Irrigation Advisory Service, performance indicators, energy audit.
Session 12

Water-food-energy nexus, eco-efficiency and ecological footprint
Moving water use efficiency up the food chain: addressing water footprints of food consumption and food wastage in the Mediterranean

Roberto Capone(1, *), Hamid El Bilali(1), Philipp Debs(1), Gianluigi Cardone(2), Nicola Lamaddalena(3)

(1) Department of Sustainable Agriculture, Food and Rural Development; (2) Department of Mediterranean Organic Agriculture; (3) Department of Land and Water Resources Management; Mediterranean Agronomic Institute of Bari (MAI-B); International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM), via Ceglie 9, 70010 Valenzano, Italy
(*Corresponding author e-mail: capone@iamb.it

Abstract:

Freshwater resources in the Mediterranean are scarce, fragile, unevenly distributed and overexploited especially for irrigation. For achieving sustainable freshwater resources use, food chains must become much more efficient. Food supply directly translates into consumptive water use. Consumed food type, composition and quantity affects water resources demand (water footprint). Since blue water resources availability is limited, crop per drop improvements, diets shifting, water saving through trade, and food losses and waste reduction are key strategies. About 30 to 50% of the food produced is lost or wasted between farm and fork. The paper aims at highlighting the importance of improving water use efficiency also in the consumption side of the food chain by analysing the water footprint of food consumption and implications of food waste in terms of water demand. Secondary data from the FAO Food Balance Sheets and the Water Footprint Network were used to: characterize the Mediterranean dietary patterns; analyse water footprints (WF) of consumption and virtual water balance in the Mediterranean; and calculate WF of food supply in Bosnia, Egypt, Italy, Morocco and Turkey. Adopting a consumption perspective, the paper identifies the consumed food products driving pressure on water resources. Northern Mediterranean countries have the highest WF of consumption per year and per capita (2279 m3) compared to North Africa (1892 m3), the Balkans (1708 m3) and the Middle East (1656 m3). That is higher than the WF of the global average consumer i.e. 1385 m3/year. In some Mediterranean countries more than a half of the WF is external. Approximately 91% of the WF is due to the consumption of agricultural products. Only Tunisia and Syria have negative net virtual water balance. Dietary energy ranges between 2,130 (Palestine) and 3,666 kcal/day/person (Turkey). The share of vegetal-based energy in the diet ranges from 66.50% in France to 88.87% in Palestine. Total WF of food supply in Italy (1848.29) is higher than in Finland (1116.69) but lower than in the USA (2198.66 m3/capita/year). The highest water footprint is the green one, followed by the grey then the blue one. Meat and dairy products represent about a half of the WF of food supply. The high Mediterranean consumptive water use is exacerbated by food losses and waste. About 10-15% of non-perishables and up to 60% of perishables are lost during the production chain. In Egypt, losses in the rice supply chain are about 25%. Food loss and wastage account for more than one quarter of the total consumptive freshwater use. A 50%...
decrease in food losses and waste at the global level would save 1,350 km³ a year. Reducing waste across the whole food system will increase water use efficiency. Adoption of more sustainable food consumption patterns and production systems and the reduction of food losses and waste can help reducing pressure on the scarce water resources in the Mediterranean. Food waste reduction interventions will have significant impact on freshwater resource availability as other water use efficiency measures in agriculture and food production thus contributing to sustainable local development.

**Keywords**: food, water footprint, waste, Mediterranean
Agri-irrigation systems under innovation: Prospects and difficulties of eco-efficiency improvements

Les Levidow¹, Rodrigo Maia², Mladen Todorovic³, Eduardo Vivas², Daniele Zaccaria⁴, Alessandra Scardigno³

¹ Open University, London, UK
² Universidade do Porto, Portugal
³ CIHEAM – Mediterranean Agronomic Institute of Bari, Italy
⁴ University of California, Davis
* Corresponding author Email: L.Levidow@open.ac.uk

Abstract:

In the Europe 2020 strategy, resource efficiency is meant to decouple economic growth from environmental burdens, especially resource inputs and pollution. A related concept, eco-efficiency denotes a relationship between socio-economic benefits and ecological burdens of the same activity. In agri-irrigation systems, the eco-efficiency can be enhanced through innovative management practices (including technology enhancement) for reducing water demand and other environmental burdens. Feasible options, incentives and difficulties to implement the eco-efficiency improvements are analysed here for two irrigation systems (Sinistra Ofanto, Italy and Monte Novo, Portugal). Alongside many differences, the two systems have some common features: numerous technologies have been adopted and others are being considered, but operators lack adequate means to know current efficiency levels and soil-hydrological conditions. Systematic rigorous knowledge is an essential basis for stakeholders to take greater responsibility for their individual water-use decisions and for organisational decisions on investments in water technology. Instead great attention has focused on hypothetical prospects – e.g. reusing external water to overcome scarcity, or reversing a statutory rise in water price. Those hypothetical prospects divert stakeholders’ attention and responsibility from feasible options.

Keywords: irrigation, eco-efficiency, water use efficiency, innovative practices, stakeholder responsibility
Eco-efficiency of a large irrigation scheme in Southern Italy: system mapping and evaluation of different management options

Andi Mehmeti (1*), Alessandra Scardigno (1), Dionysis Assimacopoulos (2), Mladen Todorovic (1), Luis S Pereira (3)

1 CIHEAM-Mediterranean Agronomic Institute of Bari, Italy
2 National Technical University of Athens, Athens, Greece
3 CEER, Institute of Agronomy, Technical University of Lisboa, Portugal
*Corresponding author ingandi@live.com

Abstract:

The objective of this work was to assess the eco-efficiency of a large irrigation scheme confronting the traditional and new technologies applications. The study area is located in the Sinistra Ofanto irrigation scheme which covers about 39000 ha of agricultural land in Apulia region (Southern Italy) and it is characterized by semi-arid Mediterranean climate. The eco-efficiency was measured as a ratio between the economic performances of the system and produced environmental impact. Indicators were used to assess the physical and economic performance of the scheme for baseline and technology configurations. Economic performance was expressed in terms of Value Added from the agricultural land use and agronomic management practices whereas the environmental performance was expressed in terms of water use [m³], groundwater abstraction [m³] and recharge [m³], energy consumption [kWh] and CO₂ emission [kg]. The analysis was performed by using the EcoWater tools, namely the Environmental Analysis Tool (SEAT) and Economic Value chain Analysis Tool (EVAT). They were used to perform environmental and economic analyses, and to support the assessment of the environmental and the economic components of eco-efficiency, both for a baseline and for alternative technologies. Based on the assessment of the current situation of the system, the following scenarios for the enhancement of the irrigation system eco-efficiency were analysed a) changing of water pricing policy and increasing of water supply b) improvement of the on-farm irrigation efficiency and water application through a larger adoption of sprinkler, drip and subsurface drip irrigation methods, c) use of variable speed pumps. The environmental performance comparison of different scenarios indicated that the priorities should be given to the application of proposed water saving technologies which affect both the reduction of water and energy use and the decrease of CO₂ emission in the atmosphere.

Keywords: water management, water-energy nexus, water saving technologies.
Sustainable “Nexus” in the Palù: Cultural Approach, Water Planning and Landscape Systems

Chiara Odolini\textsuperscript{1,*} and Erich R. Trevisiol\textsuperscript{2}

\textsuperscript{1} IUAV - University of Venice, Italy
\textsuperscript{2} ANAB (Associazione Nazionale Architettura Bioecologica), Italy
* Corresponding author: c.odolini@archiworld.it

Abstract:

The sustainable “Nexus” between resources (especially Water, Land productions for food and Energy) and the relationship between settlements and territory is a new value that we can use for re-evaluate the Veneto Region Territorial development and Landscape. The Treviso Province, the IUAV University and a private Ngo “ROMIT” have promoted an initial surveying and cataloging of “Palù in the Piave Quarter” in the north-east part of Treviso Province (Veneto Region, Italy). One of our objective was to complete and enrich the on-line catalogue of the Palù themselves. Palù is a particular field (little-closed field enclosed with a triple line of hedges, surrounded by little trenches useful for aquaculture and flood-risk prevention) used in the medieval times (1100 a.c.) from the Benedettini monks in order either to improve the local agriculture and economy (using biomass fuel) or to create a new landscape inspired to social and spiritual values. So, we are a working group that tries to highlight the landscape value, the cultural development, the economical and territorial aspect of the PALU’ fuels system. The Benedettini’ S.Bona Abbey and the surrounding Chapels create an ideal situation in order to develop an ante litteram “sustainable nexus” landscape system. The today landowners could now be a company, or a private or could be administered by either the church or the local council. Fortunately, the original structure of the PALU’ is quite well conserved (about 700 hectares as regards the original 900 hectares), even if seriously endangered by the vineyards and housing development. Our two year work, direct interview and surveys on the field will try to demonstrate the originality of PALU’ system and its reproducible capability in other places, integrated with some adaptation to its multipronged and nexus-oriented structure. A structure quite useful to the new challenges of a post-carbon and integral sustainable society.

Keywords: country landscapes, Water and Agriculture Local System, Biodiversity, Nexus Planning, cultural and spiritual approaches to the link between landscape and water
Expo 2015 Milan and Feeding Knowledge programme: the nexus between land, water, climate change, biodiversity, energy and food security in the Mediterranean

Pandi Zdruli(1*), Nicola Lamaddalena(1), Mladen Todorović(1), Alessandra Scardigno(1), Jenny Calabrese(1), Gaetano Ladisa(1), and Vincenzo Verrastro(1)

(1) International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) Mediterranean Agronomic Institute of Bari, Via Ceglie 9, 70010 Valenzano, Bari, Italy
(*)Corresponding author E-mail: pandi@iamb.it

Abstract:

Feeding Knowledge (FK) programme has been developed in the frame of 2015 Milan Universal Exposition. The theme "Feeding the Planet, Energy for Life" chosen for the EXPO2015 is related to nutrition, food security, safety and quality embraced by the common goal to achieve sustainable development that allows everyone on the planet to have access to healthy, safe and sufficient food at all times. Five priority areas have been identified in the context of the FK programme. They include: (1) Sustainable management of natural resources, (2) Quantitative & Qualitative enhancement of crop products, (3) Socio-Economic Dynamics and Global Markets, (4) Sustainable development of small rural communities in marginal areas, (5) Food consumption patterns: diet, environment, society, economy and health. The programme is first focused on the Euro-Mediterranean region including South-Eastern European countries and Turkey. After 2015, programme activities will progressively involve other regions of the world. The Mediterranean is undergoing tremendous political, economic, social and environmental changes and many challenges lie ahead but fears are that food security may be the next major “trouble”. The region is best described for its limited natural resources especially land and water, its rich biodiversity and by high population growth rates in the Middle East North Africa (MENA) region. Paradoxically, shortages of suitable land for crop production and water for irrigation or urban use are much severe in the MENA. Climate change effects are already taking their toll as the region is becoming drier and hotter imposing considerable negative consequences on crop production, biodiversity loss, ecosystem services and overall compromised environmental sustainability. On the other side, the MENA region possess considerable fossil fuel reserves and large potential for renewable energy production from wind and solar, even though these last sources are yet in the early stages of development and it is not clear what impact could have on food security. One thing is sure: the MENA countries, even by the most optimistic scenarios, not only today, but also on the medium and long term periods can’t meet the goal of being food self-sufficient via their own agricultural production and hence food-safe. They will continue to rely on food

3MENA region in this study include: Syria, Lebanon, Jordan, Israel, Palestinian Authority, Egypt, Libya, Tunisia, Algeria, and Morocco
imports compensated largely from the fossil fuel exports and tourism revenues as long as these sources would be available. Widespread land degradation and desertification but especially the inefficient and inequitable use of water, lie at the roots of many problems the region is facing, and yet, effective solutions remain elusive. The nexus between land, water, climate change, biodiversity, and energy and its relationship with food security in the Mediterranean indicate that natural resource degradation often receive a “back seat” position in the Governmental agendas. It can be reversed however, if it is caught up early and there is a political will to stop it. Research results show that there are many options available for its recovery through sustainable land and water management, biodiversity conservation, efficient use of energy sources and mitigation/adaptation actions to climate change.

**Keywords:** EXPO2015, Mediterranean, food security, natural resources, climate change, biodiversity.
Supplement to

Session 1
Water use performance and water productivity
Distributed simulation of agro-hydrological processes and assessment of water productivity in irrigated areas of the middle Heihe River basin

Yao Jiang\textsuperscript{(1,2)}, Xu Xu\textsuperscript{(1,2*)}, Guanhua Huang\textsuperscript{(1,2*)}

\textsuperscript{1} Center for Agricultural Water Research, China Agricultural University, Beijing 100083, China
\textsuperscript{2} Chinese-Israeli International Center for Research and Training in Agriculture, China Agricultural University, Beijing 100083, China
\textsuperscript{(*)} Corresponding author E-mail: ghuang@cau.edu.cn, xushengwu@cau.edu.cn

Abstract:

Irrigation is essential and significant for agriculture in the Heihe River basin of Northwest China due to water shortage and climate drought. The available water for agriculture is limited resulting from changed water allocation strategy, thus water-saving practices have been implemented. The water-saving practices may result in groundwater table decline and affect the capillary rise for vegetation water use in the basin scale. Thus it is crucial to study the influences of water-saving practices on the eco-hydrological processes and water productivity (WP). In this study, the modified Soil-Water-Atmosphere-Plant (SWAP) model was extended in a distributed manner using ArcGIS software to simulate the agro-hydrology processes. It considered the effects of combination of the weather, crop, soil and irrigation factors. The Yingke Irrigation District (YID) in the middle Heihe River basin was chosen as the typical study area. The simulated mean evapotranspiration was 563 mm for YID during the growing season, with the deep percolation of 118 mm. The deep percolation occupied 20\% of the total irrigation. The simulation results indicated that no surface runoff took place and irrigation water was assumed by evapotranspiration and deep percolation. The WP is decreasing along with the scale expanding because of an increase in water consumption item. The simulated water productivity varied from 0.88 to 1.13 kg m\textsuperscript{-3} for different sub-areas. The average water productivity of the YID is 1.06 kg m\textsuperscript{-3}.

Keywords: agro-hydrologic process, water productivity, percolation; water-saving practices; SWAP-EPIC
Alternate skip irrigation: a new strategy to ensure productive sugarcane crop with less water use

Muhammad Umer Chattha(1,*), Hassan Munir(1), Muhammad Bilal(2), Muhammad Usman(3), Mina Kharal(4)

(1) Departments of Agronomy and Crop Physiology, University of Agriculture, Faisalabad, Pakistan
(2) Institute of Agricultural Sciences, University of the Punjab, Lahore, Pakistan
(3) Department of Agronomy, Baha-ud-Din Zakrya University, Multan, Pakistan
(4) Department of Management Sciences, National Textile University, Faisalabad, Pakistan
(* Corresponding author E-mail: umer1379@yahoo.com)

Abstract:

Pakistan stands at fifth position for producing sugarcane in the world having water as life blood for it. Having semi-arid to arid climates, Pakistan needs water use efficient strategies to grow quality sugarcane for fulfilling the needs of ever expanding sugarcane industry and populace. Skip irrigation is one strategy to utilize water efficiently under scarce regimes but at the cost of precious cane yield. Alternate skip irrigation is a new technique which not only saves a bunch of water but also does not compromise on cane yield. This study was conducted to evaluate comparatively the efficiency of irrigation water under skip irrigation and alternate skip irrigation by making combinations of both techniques with quantitative levels of irrigation at 50%, 75% and 100% of total delta of water of the crop applied in a conventional flooding method to all trenches and by growing sugarcane for two years at same location in 120 cm apart deep trenches using a commercially grown variety HSF-240 fertilized with standard NPK doses along with manual and mechanical weed control. Growth parameters like plant height, internodes per cane, internodal length, number of tillers per square meter, per hectare millable canes, cane length and diameter, leaf area per plant, averaged crop growth rate, net assimilation rate, stripped cane yield, total cane biomass, harvest index and total sugar yield were significantly affected by different irrigation methods and their combinations with field moisture levels. The quality traits such as Brix, Pol, Purity of the cane juice, Cane Fiber, CCS and Sugar Recovery percentages except cane juice percentage were not affected significantly by different irrigation methods and water levels during experimental years. Maximum stripped cane yield per hectare was observed in standard irrigation treatment of 4000 mm of water which was statistically similar to alternate skip irrigation of 3000 mm of water per hectare resulting in 1000 mm water saving per hectare of land with non-significant compromise on cane yield. Farmer level adaptation of this strategy boosted the yield of cane in the water scarce Punjab province of Pakistan in the span of last five years’ time leading to saving of millions of rupees proving alternate skip irrigation with 75% of total delta of water as the best strategy to grow cane with less water under local environments of Punjab, Pakistan.

Keywords: alternate skip irrigation; efficient water use, sugarcane, stripped cane yield, Pakistan
Supplement to
Session 3
Sustainability of groundwater exploitation for agriculture
Potential Risk of Groundwater Pollution by Nitrates in Northwestern Libya

Saad A. Alghariani

University of Tripoli, Tripoli, Libya
Corresponding author Email: drsalghariani@yahoo.com

Abstract:

The Northwestern region of Libya is considered the most economically and socially important region of the country. Its dwindling limited groundwater resources and continually increasing water demand necessitated the augmentation of its water supplies through the importation of more than 800 million cubic meters per year (mcm/y) from the Southwestern regions of the country via the conveyance system of phase two of the Man-made River Project (MRP). This relatively huge volume of water is abstracted and collected from a large wellfield that comprises 484 high capacity deep wells. Unfortunately, however, the collected and imported water is characterized by a very high nitrate content that averages around 62 parts per million (ppm). In addition to its impacts on human health, if it is used domestically, this water can be a significant source of groundwater pollution by nitrates as it is intended to irrigate a targeted agricultural area of more than 100 thousand hectares distributed throughout the region. Investigation of this potential risk revealed that, in some cases, the applied water needed to meet the water requirements of the various irrigated crops in the region adds more nitrogen to these crops than their actual seasonal nitrogen demand. The excess will eventually seep down to the free groundwater aquifers with drainage water and rainfall infiltration. As most farmers are either unaware of or do not believe in the fact that their irrigation water can satisfy some of, if not all, the nitrogen requirements of their crops, the situation is aggravated by further additions of nitrogen fertilizers as if the irrigation water contains no nitrogen at all. This paper assesses the expected potential of local groundwater pollution and sets both precautionary and remedial measures and interventions to prevent its occurrence.

Keywords: Northwestern Libya, nitrates, groundwater, pollution
Supplement to

Session 4
Decision Support Systems
and modeling tools
Adaptation of water planning to climatic and hydrogeological changes

Galina V. Stulina*, G.F. Solodkiy

SIC ICWC (International Fund for the Aral Sea saving Interstate Coordination Water Scientific - Information Center)
*Corresponding author Email: galina_stulina@mail.ru

Abstract:

For Central Asia characterized by water shortage and intensive aridity one of the ways for survival is to save water resources through improvement and optimization of water use. To this end, within the framework of the IWRM-Fergana Project, along with institutional water management improvements the project developed a Management Information System, which on the basis of computer models allowed getting demands for water and its distribution among water users. Given that the main water consumer in Central Asia is irrigated agriculture (about 90% of total water supply), it is very important to identify water demand in this sector. Planning and distribution of water from irrigation system is based on hydromodule zoning. The Hydromodule zoning implies division of given area into taxonomic units (hydromodule zones) according to climatic data, soil characteristics in addition to hydrogeological and other natural and irrigation-economic characteristics of this area. Such hydromodule zoning takes into account major changes in natural-climatic and particularly in soil conditions over a 20-year period, the transformations of soil types as a result of changes in water table and irrigated land status. By using up-to-date methods for calculation of water requirements, irrigation depths, norms, and dates on the basis of GIS-based models, a methodology was developed for correction of hydromodule zone boundaries and irrigation regimes for the command area (about 100,000 ha) of the South Fergana Canal in Uzbekistan. Irrigation norms were calculated for a range of main crops by using FAO’s methodology (modified CROPWAT) for each hydromodule zone. Mapping information was processed by MapBasic in MapINFO environment. ArcINFO and MapINFO were used for conversion of geospatial data into e-format.

This work resulted in the map of hydromodule zones and tables containing recommended irrigation dates, depths, and norms based on average indicators (climate, seeding dates, etc.) that can be used by water users and practitioners. The extreme character of alternating dry and wet years has called for an adapted model of water requirements calculation that would allow correcting irrigation regime at present and, by using the method selecting an analogue-year in each decade, calculate future water requirements and forecast every next irrigation event.

The above mentioned methodology and software for assessment and, most importantly, correction of water requirements can be used for better adaptation in other irrigated zones in Central Asia.

Keywords: water management, Hydromodule, CROPWAT.
Supplement to

Session 6
Irrigation technologies
and management practices
for environmental upgrading
Calibration of ML2-ThetaProbe to Accurately Monitor Plant Root Zone Water Content in Perlite and Cocopeat

Ulas Tunali¹,*, İ.Hakkı Tüzel¹, Yüksel Tüzel²
¹ Ege University, Faculty of Agr., Agricultural Structures and Irrigation Department, Izmir, Turkey
² Ege University, Faculty of Agriculture, Horticulture Department, Izmir, Turkey
*Corresponding author Email: ulas.tunali@ege.edu.tr

Abstract:

Soilless production is growing day by day in Turkey and precise control of irrigation and fertigation is necessary. Using root zone sensors to monitor water content in substrates enables precise irrigation control and automation. A ML2-ThetaProbe sensor was calibrated for two commonly used substrates in Turkey, perlite and cocopeat. SWT-4 Rugged Tensiometers were also used for comparison. The experiments were conducted in laboratory conditions using 6 plastic pots filled with two substrates. Pots were irrigated to full container capacity, covered with plastic to prevent evaporation from top surface and left for drainage. ML2 ThetaProbes and SWT-4 Tensiometers were installed to pots and measurements were logged every 15 minutes for 5 months with DL-6 Data loggers. Two constants \((a_0, a_1)\) required for calibration of ML2 ThetaProbe acquired with experiments. Field capacity, hygroscopic water and bulk density of the substrates were also determined.

Keywords: cocopeat, perlite, thetaprobe, calibration
Supplement and Errata Corrigenda to

Session 7
Use of treated and low quality water in agriculture
Comparison of methods for determining soil C-CO$_2$ flux and analysis of the factors that affecting the flux, in growth of sugarcane irrigated with treated sewage by SDI

Eduardo A.A. Barbosa$^{(1,*)}$, Edson E. Matsura$^{(1)}$, Janaina B. Carmo$^{(2)}$, Ivo Z. Gonçalves$^{(1)}$, Daniel R.C. Feitosa$^{(1)}$, Natália F. Tuta$^{(1)}$, Leonardo N.S. Santos$^{(1)}$, Aline A. Nazario$^{(1)}$

$^{(1)}$ School of Agricultural Engineering of State University of Campinas (FEAGRI/UNICAMP), Av. Cândido Rondon, 501, Campinas/SP, Brazil. $^{(*)}$ Corresponding author's I:

$^{(2)}$ Federal University of São Carlos (UFSCAR, campus Sorocaba), Rod. João Leme dos Santos (SP-264), Km 110, Sorocaba/SP, Brazil.

$^{(*)}$ Corresponding author's e-mail: eduardo.agnellos@gmail.com

Abstract:

The study aimed check the emission rate in the cultivation of sugarcane irrigated with treated sewage (TS) and water reservoir (WR), with and without complementary fertigation of NPK by subsurface drip irrigation, determine the main physics factors that affecting the soil C-CO$_2$ flux, and compare two methods of measurement the soil C-CO$_2$ flux. The experiment was installed in Campinas, State of São Paulo, Brazil, in Oxisol soil. The treatments were: T1NI - non irrigated, with topdressing; T2EF – Irrigated with TS, with fertigation; T3ESf – Irrigated with TS, without fertilizer; T4AF- Irrigated with WR, with fertigation; T5ANf- Irrigated with WR, without fertilizer; and FA - Forest area. The drip tape was installed at 0.20 m of depth. The methods to determine the soil C-CO$_2$ flux were: IRGA, used the LICOR-8100, and the method of closed chamber with gas chromatograph analysis. The parameters correlated with the soil C-CO$_2$ flux were soil and air temperature, air pressure and volumetric soil water, for this, used analyze regression multiple and subsequently was performed analyzes multivariate. The forest area presented the highest average flux in the period. And between the sugarcane treatments – the irrigated with sewage effluent treated with complementary fertirrigation shows the highest average value of CO$_2$ flux. The infrared CO$_2$ automatic flux analyzer and the closed static chamber method with determination by chromatograph shows good correlation with the chromatography method underestimating the values which were obtained by the infrared automatic method. The main physical factors which affect the CO$_2$ flux in soil are temperature and humidity of soil.

**Keywords**: Greenhouse gases, Water reuse and Trickle irrigation.
Chemical attributes in the soil profile after six years of cultivation with irrigated and fertigated coffee at two planting spaces

Eduardo A.A. Barbosa\textsuperscript{(1,\ast)}, Emilio Sakai\textsuperscript{(2)}, Jane M.C. Silveira\textsuperscript{(3)}, Regina C.M. Pires\textsuperscript{(2)}

\textsuperscript{(1)}School of Agricultural Engineering of State University of Campinas, Av. Cândido Rondon, 501, CEP:13083-875, Campinas/SP, Brazil.
\textsuperscript{(2)}Campinas Agronomic Institute, Av. Theodureto Camargo, 1500, CEP:13075-630, Campinas/SP, Brazil.
\textsuperscript{(3)}São Paulo’s Agency for Agribusiness Technology, Av. Presidente Castelo Branco, s/n, CEP:13730-980, Mococa/SP, Brazil.
\textsuperscript{(\ast)}Corresponding author’s e-mail: eduardo.agnellos@gmail.com

Abstract:

The objective was to evaluate the effect of irrigation and fertigation on chemical attributes of the soil and root system, after 6 years of coffee arabica cultivation at two planting spaces. The experiment was carried out in Mococa-SP, Brazil, with \textit{Coffea arabica} L. seeding in March 2006. The climate according to Köppen is Cwa and the soil was classified as medium textured eutrophic Alfisol. The experimental design was a 2 x 2 factorial scheme, with three replications. The factors were the two planting spaces, 1.6 and 3.2 m between the rows, divided in treatments irrigated with fertigation (IF) and non irrigated with topdressing (NI). The volume of water applied depended on the irrigation interval and the climatic demand (ETc). In August 2012, trenches were opened to collect soil in the profile. In each trench the soil was collected in a mesh with dimensions of 1.60 m vertically and 0.80 m horizontally. In the vertical axis, soil was collected in five points, with the stem of coffee as the central point. In horizontal axis, the soil was collected every 0.20 m, till the depth of 0.80 m. After soil sampling, to determination of pH, electrical conductivity (EC), base saturation (V\%) and cation exchange capacity (CEC), and was determined the distribution of roots, used a mesh of 2.5 x 2.5 cm. The mean test was performed and maps were created using the program Surfer 4.0. The use of the IF decreased the soil pH, mainly close to the stem and between 0.0-0.60 m, where the pH ranged from 4.7 to 5.0. At the similar region in NI cultivation, the soil pH ranged from 5.6 to 5.9. The IF increased the EC at the central point, in all of the layers of soil profile (0-0.80 m), with the soil EC ranging from 0.96-1.29 dS m\textsuperscript{-1}, where as the values for NI ranged from 0.52-0.74 dS m\textsuperscript{-1}. The NI presented higher EC in the layer of 0-0.20 m, and 0.40 m to right of stem, where was held topdressing, when compared with IF. The IF reduced the V\% in the central region of the soil profile, with values ranging from 36-46\%, whereas the values for NI treatment ranged from 58-62\%. The NI reduced V\% in the region of 0.40 m from the stem, on both sides, in the layer of 0-0.20. The coffee grown at 1.6 m spacing decreased the soil pH in the layer 0.20-0.40 near the stem, when compared with spaced 3.2 m. The 1.6 m spacing showed higher values of EC in relation to 3.2 m spacing. The 3.2 m spacing showed high CEC in the region near the stem, and the base saturation showed little variation when comparing 1.6 and 3.2 m spacings. The
distribution of the root in the IF showed higher concentration of roots in the region near the row planting, already in the non-irrigated coffee roots showed higher concentration on the sides of trench. The spacings showed low differentiation in the distribution of the root system.

**Keywords:** Drip irrigation, Fertilizer, Profile maps of soil.

---

*Errata Corrigenda:*

Page 151, row 6, authors of abstract: should be written “Antonio Lopez” and Roberta Lamaddalena” instead of “Antonio Lopez”
Supplement to

Session 8
Climate change: adaptation and mitigation
Introduction and assessment of quinoa in Pakistan as a potential climate resilient grain option for future food security

Hassan Munir(1), Muhammad Umer Chattha(1,*), Shahida Yousaf(2) and Saeed Rauf(3)

(1) Departments of Crop Physiology, University of Agriculture Faisalabad, Pakistan
(2) Department of Agronomy, University of Agriculture Faisalabad, Pakistan
(3) Department of Social Sciences & Humanities, University of Agriculture Faisalabad, Pakistan
(4) College of Agriculture, University of Sargodha, Sargodha, Pakistan
(*)Corresponding author E-mail: hmbajwa@gmail.com

Abstract:

Quinoa is a widely adaptable grain native of Latin American Andean high mountains. High climatic resilience especially under biotic and abiotic stresses reasoned its adaptation by the climate prone countries of the world. Pakistani environment is facing climate change phenomena equally like other climate prone countries. Scarcity of irrigation water, less and unexpected rain fall, frost and exceptionally high temperatures contributed to an environment where conventional crops often faced failure in the past and to date. Diversity in conventional cropping scheme has highlighted the need of climate proof/resilient grain crops for assurance of food and feed in the region. Quinoa is among these crops those under extensive investigation were successfully reported to grown in variety of regions of the Punjab province of Pakistan. It was established that the quinoa germplasm belonging to native lands of Chile proved high grain yielding in the planes of the Punjab whereas the Bolivian germplasm was significantly better performer in the salt range highlands approx. 500 m.a.s.l. significant variation among the germplasm was observed regarding plant height, number of branches and leaves per plant, number of panicles per plant, 1000 grain weight, leaf chlorophyll content, leaf carotenoids and total phenolic content. Similarly, higher yielder accessions of quinoa were also evaluated using proline as a biochemical marker with significant comparison among the accessions. Highly stable accessions were identified to mitigate the effects of climatic shocks. CPI-1HMB, CPI-2HMB, CPI-7HMB and CPI-9HMB were proven potential accessions which can be recommended for cultivation from sea level to moderately high altitudes of the country. However, further investigation is needed to execute experiments in the regions of Karakoram and Himalaya where low temperature stress majorly implicates growth and yield of field crops. Furthermore, growth and yield expression of quinoa under these regions give impetus to speculate that quinoa can be a potential choice for substitution of climate susceptible grain crops of the region and it can be exported to leading developed countries for earning foreign exchange due to its high price in the international market.

Keywords: quinoa, Pakistan, adaptability, yield, cash crop
Supplement to Session 11

Policies, governance and institutional development
Performance Evaluation of Transferred Irrigation Schemes of Gediz Basin, Turkey

Sultan Kiymaz\(^{(1,\,*)}\), Atef Hamdy\(^{(2)}\)

\(^{(1)}\) Ahi Evran University, Faculty of Agriculture, Department of Biosystem Engineering, Kırsehir, Turkey

\(^{(2)}\) Emeritus professor, Mediterranean Agronomic Institute of Bari, Italy

\(^{(\ast)}\) Corresponding author E-mail: skiymaz@ahievran.edu.tr

Abstract:

Irrigation management transfer (IMT) is known as the transfer of authority and responsibility to manage irrigation system units from public agencies into private-sector entities, such as water users associations or into local administration units. The main aim of IMT was to achieve improvements in the performance of the irrigated agriculture sector, including both agricultural productivity and financial and physical sustainability of irrigation schemes. Most of the performance evaluation systems were developed for comparative purposes. In this regard, to manage irrigation systems effectively and sustainably are needed the evaluation and monitoring of WUAs in terms of performance criteria. This study was carried out in the Water User Associations in Izmir and Manisa provinces, located in Gediz Basin. The objective of this study is to compare performance indicators for irrigation schemes before and after turning-over to Water User Associations (WUAs). For this reason, in the study the selected WUAs are evaluated by using some physical, economical and institutional indicators. The physical performance of irrigation schemes are evaluated in terms of irrigation rate, the sustainability of the irrigation area and water supply. The economic performance of irrigation schemes is assessed by using the criteria of efficiency of water fee collection and financial self-sufficiency. Institutional performances of irrigation schemes are evaluated in terms of staff intensity. In addition to this, the equivalent technique statistically was used to determine whether there is a significant time dependent changes in values of the performance related to before (1987-1994) and after (1995-2004) turn-over period. All data related with the performance indicators are taken from the records of monitoring and evaluation of the State Hydraulic Works (DSI) and bulletin of the WUAs. According to the result of the performance indicators, the most tangible and positive chance has occurred in the collection of irrigation water fees. Some other criteria were also improved after transfer to water user associations.

Keywords: Irrigation management transfer, water user associations, performance indicators, turning-over, Gediz Basin
Women in climate change adaptation and mitigation

Rosanna Quagliariello* and Atef Hamdy

CIHEAM – Mediterranean Agronomic Institute of Bari, Via Ceglie 9, Valenzano (BA), Italy
*Corresponding author Email: quagliariello@iamb.it

Abstract

Adapting to climate change will require a broad range of efforts, incentives, resources, commitment and active interventions through the outmost parts of society. As women constitute half of the world population, climate change adaptation and mitigation policies must address the gender issues. Women should be at the center of adaptation and mitigation programmes because they are a particularly vulnerable group due to the limited access, control and ownership over resources, unequal participation in decision and policy making, lower incomes and levels of formal education and extraordinary high workloads. On one hand, apparently, women are more vulnerable to climate disasters than men because of their socially constructed roles and responsibilities and their relatively poorer and more economically vulnerable position. On the other hand, women need to be at the hearth of adaptation efforts because of the significant roles they play in agriculture, food security, household livelihoods and labor productivity.

Women, despite being affected from climate change, their role in adaptation and mitigation is praiseworthy. They generally possess a strong body of knowledge and expertise regarding their surroundings that have accumulated over time through their active involvement in resources management which could be used in climate change mitigation, disaster risk reduction and adaptation strategies.

More practically, in many developing Countries, women are found in building anti-flood embankment and increasing off-farm employment during crisis which can be best illustrated as coping mechanisms against climate change. Unfortunately, women are often portrayed as unworthy and incapable of engaging themselves in environmental and climate change related negotiations and strategic planning. This historical neglect and invisibility of women’s role ought to be reversed. It is high time to incorporate gender issues in environmental and climate change policies and actions from a human rights point of view.

Keywords: gender, adaptation, mitigation women, climate change.
The System of Knowledge Transfer and Risk Management in Irrigated Agriculture

Viktor A. Dukhovny¹* and Shukhrat Mukhamedjanov¹

¹ Scientific Information Center of Interstate Coordination Water Commission (SIC ICWC), Tashkent, Karasu-4, building 11, 100187, Uzbekistan
*Corresponding author Email: vdukh@yandex.ru

Abstract

The agrarian sector in Central Asia and Caucasus, as well as in the Eastern Europe undergoes radical transformations, involving restructurization of agriculture, transfer from large state and collective farms to smaller private or leased farms. Former practitioners with broad experience often were replaced by new masters of farm, who had money, but needed skills and recommendations for efficient crop production and development of multiple agrarian branches. Modern science has enough experience, achievements and practical recommendations, as well as seed material, new solutions, tools and approaches that may successfully respond to most of problems that the present agricultural producers face. However, those tools are remote from the general knowledge consumer – farmers, staff of farmer associations and providers of various services who have limited access to knowledge sources and weak connections with research and education centers generating this knowledge.

Present agriculture is an industry experiencing continuous risks. In the past, agriculture depended largely on weather conditions, uncertainties of flow probability and climate, attacks by diseases and pests, possible variation in agricultural output prices. By present, the degree of risk has increased significantly due to changes in public policy and institutional structure of the agrarian sector, incomplete formation of the whole its infrastructure, weakening of state support, and, above all, quite new conditions of functioning under poorly developed market relations and marketing. Besides, now farmers have to find suppliers themselves and establish relations with buyers under increased variations in prices of agricultural outputs and inputs (fertilizers, fuel, chemicals, etc.). Unfortunately, none of Central Asian countries has a well-arranged extension service system. Establish a system for transferring knowledge and best practices, including scientific developments, to farmers and their organizations in order to ensure growth of productivity and risk management in agriculture.

This proposal is founded on experience of innovation adaptation centers developed within the framework of socialist production and on principles of land and water productivity improvement that were formulated and tested within the IWRM-Ferghana and Water and Land Productivity Improvement projects by SIC ICWC together with IWMI, with the involvement of water-management organizations from Kyrgyzstan, Tajikistan, and Uzbekistan, under support of SDC.

Keywords: Central Asia, Caucasus.
Managing scare water resources under competing demands: Zayandeh-Rud basin, Iran

Safieh Javadinejad

School of Geography, Environment and Earth Sciences, University of Birmingham, Birmingham, UK, B15 2TT; PH(+44)1214145682. Corresponding Author Email: sxj228@bham.ac.uk.com

Abstract:

Within river basins different social, political and physical sub-systems interact. While making decisions, policy makers should be aware of such interactions as any new policy will affect more than one subsystem. To identify the sufficient of a specific management system in the basin considering major physical, social and political aspects. As same as many countries in the world, experiencing extreme water shortages, Iran is also in a serious water crisis. With mostly arid and semi-arid climatic conditions, the country is facing an extreme water shortage. Currently the problem has become more visible due to the recent droughts witnessed in specific parts of the country such as Zayandeh-Rud river basin in Esfahan city. In addition the basin with complicated watershed system where the lack of complete knowledge about all the interacting subsystems and also mismanagement have led to failure of the policy makers in addressing the water shortage in the basin. While water shortages happen soon fairly after completion of each new water source, transbasin water diversion is still the big policy of water planners to address on going shortages. System dynamics makes a unique framework for integrating the disparate physical, socio and political systems important to watershed management. This approach is applied to comprehend the interactions of different drivers and a simulation model (WEAP) makes demand priorities and supply preferences, which are used in a linear programming heuristic to solve the water allocation problem as an alternative to multi-criteria weighting or rule-based logic approaches. The results of the model for various scenarios suggest that different options of demand management and population control can be more effective in addressing the water crisis of the basin when combined with transbasin water diversions, increasing water storage capacity and controlling of groundwater withdrawal.

Keywords: Sub-systems interact, Management system, Water shortage, Drought, System dynamics, WEAP, Water allocation, Demand management, Population control.
Supplement to

Session 12
Water-food-energy nexus, eco-efficiency and ecological footprint
Planning food waste

Elina Sirén, Gerrit J. Carsjens*

Wageningen University, Land Use Planning, P.O. Box 47, Wageningen, the Netherlands
*Corresponding author Email: gerrit-jan.carsjens@wur.nl

Abstract:

Urban food strategies aim to connect the various food related public domains within a city region, such as spatial planning, environment and public health. Food strategies are slowly becoming part of the work of spatial planners and food system planning a legitimate field of planning research. However, the emphasis in planning research has been mainly on the production, processing and retail parts of the food chain, while research on both consumption of food and waste treatment is lacking. This research aims to identify how food waste is being addressed in urban food strategies and in what ways spatial planning can facilitate the handling of household food waste in city regions. The research involved two case studies in London (UK) and Toronto (Canada). From the research can be concluded that urban food strategies appear not have much influence on food waste management yet. However, facilitating urban agriculture showed to be an important part of both urban food strategies and this may indirectly facilitate composting and re-use of compost in urban agriculture. The possibilities for spatial planners to facilitate waste management in urban areas are limited, although some options were identified. These also require awareness raising, since not all planners at the local level are aware of the existence of a food strategy.

Keywords: organic waste, food strategy, waste recycling, spatial planning, waste management
Agricultural and industrial applications of geothermal energy

Bouzidi Khedidja, Ouali Salima
Centre de Développement des Energies Renouvelables (CDER), Hydrogène & Energie Renouvelable, B.P. 62 Route de l’Observatoire, 16340, Algiers, Algeria.

Abstract:

In recent years geothermal research knows a considerable progress in several countries of the world. The high temperature geothermal resources are used both for electricity and heat production, while the low temperature geothermal resources remain largely untapped, despite their abundance. In this paper, we propose to give a general overview of high and low temperature geothermal resources and define the possibilities of their use especially in industrial and agricultural sector.

Keywords: geothermal resource, low temperature, high temperature, application, agriculture
Possibility of agricultural geothermal utilization in south Algeria

Salima Ouali, Khedidja Bouzidi

Centre de Développement des Energies Renouvelables (CDER), Hydrogène & Energie Renouvelable, B.P. 62 Route de l’Observatoire, 16340, Algiers, Algeria.

Abstract:

The South of Algeria contains two important geothermal reservoirs in depth at geological formations of the Intercalary Continental (IC) and the Terminal Complex (CT). These two aquifers that constitute the North Western Sahara Aquifer System (NWSAS) are considered as the largest water reserves in the world.

Keywords: geothermal reservoir, Intercalary Continental, Terminal Complex, Albian, agriculture.
Water, agriculture and environment are intrinsically linked either considering the water pathway in the hydrological balance, or through the components of soil-water and energy balance, or the simple relations explaining water/resources productivity. Agriculture consumes about 70% of the world’s water withdrawal and, due to limited availability of water, land and other natural resources, we face the enormous challenge of promoting the sustainable use of the resources, producing more with less, and respecting the environment and the future generations.

The 1st Inter-regional Conference on Land and Water Challenges, held in Bari (Italy), 10-14 September 2013, was planned on the above stated premises with the objective to discuss the latest achievements in the field of sustainable use of natural resources at different scales and promoting a better development of agriculture in the future. The event was organized jointly by CIGR (International Commission of Agricultural and Biosystems Engineering) and CIHEAM (International Centre for Advanced Mediterranean Agronomic Studies) – Mediterranean Agronomic Institute of Bari (IAMB), Italy. The proceedings of the Conference contain printed copies of abstracts and electronic copies of full papers, more than 110 contributions from all over the world: Africa, North and South America, Asia and Europe. (Eds.)