European Territorial Cooperation Programme
Greece - Italy
2007-2013

INVESTING IN OUR FUTURE
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Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes

IRMA

WP2, Action 2.2, Deliverable 4

Open international conference (Italy), theme: "Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes"

Organization of Conference in Italy (Irrimed 2015)

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IRRIMED 2015

International Conference on

"Modern technologies, strategies and tools for sustainable irrigation management and governance in Mediterranean agriculture"

(IrriMed 2015)

Valenzano (Bari, Italy), 23-25 September 2015

Proceedings - Book of Abstracts

Editors:

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European Territorial Cooperation Programmes (ETCP)
GREECE-ITALY 2007-2013

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Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscape

REGIONE PUGLIA
Area politiche per lo sviluppo rurale / Dept. of rural development
Servizio agricoltura / Direction of agriculture
Ufficio innovazione e conoscenza in agricoltura / Innovation and knowledge in agriculture office

CNR - ISPA National Research Council - Institute of Sciences of Food Production, Italy

CIHEAM Mediterranean Agronomic Institute of Bari

ISBN 2-85352-549-X

IRMA (Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes, www.irrigation-management.eu) is an ETCP GR-IT 2007-2013 project. Its outputs include irrigation surveys, application manuals, auditing procedures, development of web tools for irrigation information and recommendations based on actual metereological data, satellite images and GIS mapping for irrigation management counseling, research results, creation of a networking platform and actions for public consciousness building and professional training-certification regarding strategies and methods for efficient irrigation management. More than 500 irrigation and drainage stakeholders from Greece, Italy and beyond followed the implementation of the project and are expected to be benefit from its outputs.

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- Analysis of time-series MODIS 250 m vegetation index for tree-crop systems
- Yield and Quality Response of Wheat to Saline Irrigation in the Mediterranean Environment
- A First Year of Comparison Between Ordinary Drip Irrigation and Subsurface Drip Irrigation (SDI) in a cv. ‘Greco b.’ Vineyard
- Effects of particle film technology on tomato under salinity stress
- The DSS GesCoN for managing irrigation and fertilization in vegetable crops. Application in processing tomato crop in southern Italy

WELCOME

Water is a vital resource, a primary element for humans and an essential source for the survival and development of any productive sector. It is responsibility for everyone, as well as for institutions, defend, protect and preserve water as the essence of life and the security for future generations.Hence arises the modern setting of water management in agriculture, based on stringent criteria of efficiency and environmental protection, required also by EU and national legislation.

The threat of climate change, the effects of which have an impact on the water cycle and are particularly evident in the Mediterranean area, requires an integrated approach among the water policies, over and above the geographical, economic and social dimension of subjects or sectors involved. It is therefore necessary to ensure policies based on governance models compatible with the limited water resources, with respect to the competition among the various demands of use, and that also take into account the trend of its consumption and its availability.

For the Region of Puglia the theme is strategic and results in investments in the knowledge of new solutions and approaches for the efficient and sustainable management of irrigation water, through the IRMA project.

The work carried out in the framework of the Project is the result of a virtuous partnership between the Region of Puglia, the National Research Council – Institute of Sciences of Food Production (CNR - ISPA) and the Council for Research in Agriculture and Agricultural Economic Analysis (CREA), in close collaboration with the Greek partners. Special thanks is due to all of them. Decisive for the international conference IrriMed 2015, organized by the Region of Puglia, with the valuable participation of many experts and researchers, was the contribution of skills and experience of the International Centre for Advanced Mediterranean Agronomic Studies – Mediterranean Agronomic Institute of Bari (CIHEAM-IAMB).

Farmers of Apulia and, more generally, of the Mediterranean territories are living water scarcity as a daily challenge. The works collected in this book are the building blocks for the construction of new knowledge and innovation in the field of optimization of water resources use for irrigation, to support rural areas of the Mediterranean basin, which express incessant needs.

Leonardo Di Gioia

Assessore all'Agricoltura - Risorse Agroalimentari, Regione Puglia

Assessor to Agriculture - Agrofood resources, Region of Puglia

PREFACE

In most Mediterranean countries water availability is a main concern for agriculture, which uses for irrigation up to 70 % of this resource.
Nowadays, modern agriculture has to face the increasing scarcity of water for irrigation, as a result of the reduced availability and the increasing competition of civil and industrial sectors. The future scenario, resulting from climate changes, could intensify the irrigation requirements for crops, especially in those geographical areas characterized by high evapotranspiration demand, traditionally affected by water restrictions. This will result in the imperative need of policies for rational water management. At the same time, the adequate availability of water for irrigation is critical for raising the profitability of crops, both through the increased productivity and the possibility to achieve high quality standards, appropriate to the demands of the modern consumer. This aspect is of primary importance in Mediterranean countries, characterized by high consumption of fresh horticultural products. However, misguided irrigation practices can raise several environmental problems, such as depletion, pollution and progressive groundwater salinization, erosion and salinization of soil. Therefore, it is essential that the water resources governance will be sustained by the scientific support of research institutions in the definition of the most effective strategies to rationalize the use of water for irrigation, with the double aim to reduce the amount of water used and to maintain high agricultural productivity, both in terms of quantity and quality. The accurate assessment of crop water demand is the essential requirement for rational management of water, followed by its rational distribution to plants. This is the framework of the IRMA project ("Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes'). The project is funded under the European Territorial Cooperation Programmes (ETCP) Greece-Italy 2007-2013, in which Italian institutions (Puglia Region, CNR-ISPA and CREA) closely cooperate with Greek institutions (TEIEP, ROEDM and AEPDE) with the aim of encouraging the exchange of knowledge between partners, through the development of practical tools and new practices for irrigation management, and sharing scientific experiences in specific areas such as greenhouses, public parks, and open field crops. In the certainty that the integration between different institutions and actors (research, politics, public administration, etc.) represents an extraordinary instrument to ensure the progress of knowledge, transfer and adoption of innovations, I am sure that this conference will trigger further and fruitful synergies and collaborations both at national and international level.

Antonio F. Logrieco
Director of the Institute of Sciences of Food Production (ISPA)
National Research Council (CNR)

FOREWORD

The International Centre for Advanced Mediterranean Agronomic Studies – Mediterranean Agronomic Institute of Bari (CIHEAM-IAMB), Italy, organized the International Conference on "Modern technologies, strategies and tools for sustainable irrigation management and governance in Mediterranean agriculture" (IrriMed 2015) in straight collaboration with the Apulia Region and the National Research Centre – ISPA (Istituto di Scienze delle Produzioni Alimentari). This is just one of numerous examples of collaboration between these two scientific Institutions and Apulia Region.

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 water use efficiency and water/resources productivity. Actually, agriculture consumes about 70% of the world's water withdrawal and, due to limited availability of water, land and other natural resources, the challenge of our era is to promote the sustainable use of the resources and to produce more with less with a respect of the environment. In the last decades, the irrigation management has been getting more importance due to necessity to improve the efficiency of resources use in agricultural sector. The agronomic practices and engineering infrastructures have to be considered together with organizational, institutional, social, cultural problems as well as integrating activities of operation, maintenance and management. Moreover, the continuous technological progress leads to notable changes in irrigation equipment while innovation resulting from automation induce the farmers to behave in a way different from the one assumed at the design stage. In addition, the governance of resources and infrastructures is getting more complex due to increased demands and almost fixed or even reduced availability of resources. In the years to come, the relationship between water, energy, environment and agriculture is going to be more tight, functional and multifaceted due to a series of reasons comprehending primarily the accelerating changes in population growth, climate and land use. By the mid of this Century, the world population will reach at least 9 billion and agriculture will need to produce almost one-third more food than today with the unchanged or even reduced water and land input and under more variable and adverse climate. Certainly, many other changes will occur meanwhile including the political and financial arrangements, technological and socio-economic development, cultural setup, consumption pattern, and living and nutritional habits. This might create numerous scenarios describing the water-agriculture interlinks within the systems at local and global scale and deriving the possible implications on the availability and quality of water

and land resources, the natural ecosystems and agricultural production. Efficient Irrigation management is, therefore, getting increasing importance since availability and quality of fresh water resources and the sustainable use of soil resources are under increasing pressure. Given the physical limitations of land and water, the link between food security, land use and water resources is particularly important for arid and semi-arid areas of Mediterranean. New strategies, approaches and tools are required in order to address irrigation water management, and performance and productivity of agricultural systems. This Conference is going to address this important issue and I would like to thank all outstanding experts and participants for their valuable contribution in promoting sustainable irrigation management and governance in the Mediterranean region.

Cosimo Lacirignola
Secretary General of CIHEAM, Paris

INTRODUCTION

Water scarcity is becoming a real threat to the sustainability of irrigated agriculture. This issue is of primary interest in Mediterranean countries, where population dynamics, upgraded standards of living, economic and social development, and the use of water-consuming technologies require careful and continuous assessment of models and strategies for water resources use. The increasing competition for water resources has raised the interest of consumers and governments to adopt water conservation practices and to limit environmental burden. The focus is turned towards increasing the efficiency of water use in the Mediterranean agricultural systems since agricultural sector is the major consumer of water resources. This means also the development of optimal governance strategies considering the multiple interest of various stakeholders in water sector. The failure to adopt appropriate strategies for irrigation management could lead to further deterioration of resources and extended water shortage in Mediterranean agro-environments.

Irrigation management embraces a set of technical, socio-economic and environmental issues. Management decisions directly affect the whole chain of water delivery and its application to the fields. Hence, irrigation practices affect crop performance and can lead to qualitative and quantitative improvements in agricultural production. In turn, efficient irrigation management also contributes to the reduction of environmental impact and sustainable use of resources.

On the other hand, excessive irrigation results in low water use efficiency, leaching, and runoff of water, fertilizers, and other agrochemicals, contributing to make agriculture an important source of non-point source pollution.

With this background, the IRMA project ("Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes"), granted in the framework of the European Territorial Cooperation Programmes (ETCP) GREECE-ITALY 2007-2013 (http://www.irrigation-management.eu/), has been launched on April 2013, with the aim to establish a network of knowledge and expertise exchange which will lead to the development of practical irrigation management tools for demand-driven capitalization of scientific knowledge and good practices. The closing event of IRMA is the International Conference on "Modern technologies, strategies and tools for sustainable irrigation management and governance in Mediterranean agriculture" (IrriMed 2015), held on 23-24-25 September 2015 in Valenzano (Bari, Italy). IrriMed 2015 has been organised by Regione Puglia (Italy), with the scientific support of the Institute of Sciences of Food Production (CNR-ISPA, Bari, Italy) and in the partnership with the Mediterranean Agronomic Institute of Bari (CIHEAM-IAMB, Bari).

IrriMed 2015 has been focused on the presentation of the latest scientific and technological achievements in the irrigation sector, with the ambition to offer a platform for discussion and debate among actors and stakeholders involved in the management and governance of water for agricultural use. Both scientific research advancements on irrigation practice and water resources governance topics have been covered in the sessions of the Conference.

The present "Book of Abstracts" includes the abstracts of the presentations (oral and poster) included in the Conference programme. The abstracts are presented according to the sessions of the Conference: Water governance; Environmental, social and economic aspects of water management; Use of non-conventional water resources; Soil-plant-atmosphere continuum; Innovative tools for irrigation management at farm and district level; Modern strategies for water management under protected environment; Modern strategies for water management for open field crops.

The IrriMed 2015 Conference attracted participants and presenters with different background (scientific, administrative, commercial), coming from a wide range of areas of the Mediterranean Basin. We thank all of them for their interest in IrriMed 2015, and for helping us in giving life to this event.

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OPENING SESSION

WATER EFFICIENCY, WATER PRODUCTIVITY AND WATER SAVING: BETWEEN CONFUSION AND EFFECTIVE SOLUTIONS

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Extended Abstract

Regions naturally exposed to a chronic shortage of water, like it is the case for the NENA, are facing severe intensification of water scarcity due to numerous drivers: demographic growth, policies to increase food self-sufficiency to reduce import vulnerability and price volatility, urbanization expansion, high energy demands, and overall advance in socio-economic devel¬opment. Furthermore, the anticipated impact of climate change compounds the already difficult and complex settings. Developing strategies for sustainable water resources management under water scarcity is therefore of paramount importance.

Scientists, planners and policy makers look at scenario analysis of future water demands, criteria for optimal water resources allocation between sectors, review food, water and energy security policies, and several other measures, in the attempt to ensure that countries under water scarcity are aligned with the imperatives of (i) setting the sustainable limits of water consumption and (ii) making the best use of each single drop of water, including the use of non-conventional water sources (FAO, *Regional Initiative on Water Scarcity*, 2014).

In the case of the NENA, irrigated agriculture is the single largest user of fresh water resources accounting for 85% of the total water withdrawal. Even relatively low percentage of water saving in irrigation would be of enormous benefit for other sectors and for the environment at large. Agriculture has a vested interest and shared responsibility in the sustainability of future water resources management through higher performance, efficiency and productivity.

Interestingly, the majority of measures observed in irrigated agriculture in response to water scarcity are dealing with efficiency and productivity '*of each singe drop of water*' (point ii above) through modern or hi-tech irrigation. The underlining assumption is that increasing efficiency and productivity of farm irrigation leads to corresponding saving of water resources and eventually makes the saved water available for other users. Unfortunately, this assumption is a fundamental mistake in agricultural water resources management. This notion has induced countries to invest several hundreds of millions of dollars in converting traditional irrigation systems (e.g., surface or furrow, with application efficiency of the order of 50%) into modern irrigation systems (e.g., localized, with application efficiency of the order of 85%) resulting in a series of benefits except water saving and has even worsened

their water scarcity condition.
These unintended results are the consequence of not applying in the water-saving analysis a robust water accounting framework like the one proposed by Willardson et al. (1994), supported by the International Commission on Irrigation and Drainage (ICID), re-emphasized by Perry (2011), and utilized here. For water productivity, the reader is referred to Steduto et al. (2007) and Molden et al. (2010).
To determine whether we are saving water through a modernization investment, a technical intervention or a management practice in irrigation, it is necessary to know where the water goes when applied to the field. It can be in part '*consumed*' through evapotranspiration. We use the term '*consumed*' because when water evaporates into the open atmosphere (change of phase from liquid to vapor) it is no longer available to the system under consideration. The '*consumed*' fraction of water can be further distinguished as '*beneficial*' (i.e., consumed for the intended purpose – for instance to obtain crop yield) or '*non-beneficial*' (i.e., consumed for purposes other than the intended ones – for instance evaporated by bare soil or transpired by weeds). But the water applied to the field can be in part '*non-consumed*'. In this case, it remains in liquid phase and stays into the system generally either percolating underground or running off from the field. The '*non-consumed*' fraction of water can be either '*recoverable*' (i.e., it can be captured and reused – for instance by farmers downstream or by return flow to a river) or 'non-recoverable' (i.e., it is lost to further use – for instance it ends into very deep aquifers not economically exploitable, or into very saline groundwater, or flows to the sea, or even stagnates into the soil).
Let's take the case of a farmer pumping groundwater and irrigating his/her crop with surface methods and having an application efficiency of 50%. This means that if 50 units of water are to be '*consumed*' by the crop, 100 units of water need to be applied to the field. The 50 unit in excess are either percolating back to the groundwater (although with a degraded quality), or running off from the field and in part evaporated as '*non-beneficial*' consumption. The common 'thinking' is that if we incentivize the farmer to convert his/her irrigation system from surface to localized irrigation (e.g., drip), with an expected increased efficiency to 85%, the farmer can 'save' about 41 units of water. Here is where the confusion comes in. Before asserting that a water saving has occurred we need to know whether the '*non-consumed*' fraction of the previous 50 units in excess were '*recoverable*' or '*not-recoverable*' (we consider here as minor the difference in '*non-beneficial*' consumption between the two irrigation methods). If the water was '*recoverable*' (like it is often the case), then there is no water saving. In fact, only if the '*non-consumed*' water is '*non-recoverable*', then the increased irrigation efficiency leads to actual water saving. Not only, worldwide observations show that (e.g., Berbel et al., 2015) the economic benefits of hi-tech irrigation tend to make water more valuable to farmers so that they continue to pump water and with the extra units gained through efficiency they expand the irrigated area. Therefore, the end result is an increase in '*consumed*' water. Similarly, as another example, selecting varieties considered of higher water productivity has not resulted in any water saving either.
Increased efficiency and productivity through modern irrigation systems would definitely lead to a series of benefits for the farmer and for the system in general, such as: increased yield, reduced pumping costs, minimized fertilizer application, decreased labor costs, reduced groundwater pollution, etc. However, in most cases

higher efficiency and productivity do not lead to water saving. To determine whether water saving does occur, it is necessary to apply the above-mentioned water accounting framework and make sure that the '*non-beneficial consumption*' and the '*non-recoverable fraction*' of water use in irrigated agriculture are actually reduced (Perry et al., 2009).

The cumulative experience of research and field application has demonstrated that sub-surface irrigation, mulching, changes in cropping patterns, and regulated deficit irrigation (RDI) are among the effective solutions for saving water in open field of a pre-determined irrigated area. However, as previously indicated, the water saved through these measures frequently induces farmers to expand their irrigated surface so that the overall water consumption at country/basin level is increased. Therefore, this risk of increased consumption is managed only if the measures are accompanied by limiting the overall irrigated area (Berbel et al., 2015). In protected agriculture, new generation green-houses (NGGH), which condense and re-use the water transpired by plants, is another effective solution to save water.

The major conclusion is that, when concerned with water saving and the sustainability of scarce water resources management, setting the limits of water consumption is the first line of action to be undertaken. Within these limits, all possible measures need to be implemented to make the best use of each single drop of water substantiated through the adoption of a solid water accounting framework.

Keywords*: hi-tech irrigation, water accounting, water consumption, water scarcity*

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SESSION:

WATER GOVERNANCE

WATER GOVERNANCE IN IRRIGATED AREAS: MODELS, PRINCIPLES AND INNOVATIVE SOLUTIONS

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Extended Abstract:

Introduction

The Governance of irrigation water is analysed in this context as the organization of an irrigated area. While there is no clear definition for "irrigated area", one can assume that it corresponds to the first level of collective organization for water allocation, distribution, application and drainage. Different irrigation projects around the world have resulted in different sizes and degrees of complexity of irrigated areas, but in general they comprise extensions ranging from 10 to 10,000 ha. The fact that the concept is subjected to a range of extension of three orders of magnitude suggests that plenty of managerial, technical and organizational variability is involved.

Water governance actually comprises two types of functions: directive and executive. Only in large, well organized districts both functions are clearly separated. In these cases, a Governing Board is responsible for strategic decision making while an Executive Body (a Director and its assistants) is responsible for implementing these strategic decisions and making tactical decisions. A "Terms of Reference" document for the governance structure is required to specify the responsibilities of both bodies. While problems can accumulate at both levels, the Governing Board stands high probability of failure, due to the non-professional nature of its components. These are often respectable local leaders, which frequently find it difficult to follow technical discussions and can only devote a small part of their time to fulfil their responsibilities. The presence of professionals in the Executive Body has often resulted in very good managerial results, since in many areas of the world the liability of irrigation governance structures is growing fast. The fact that small irrigated areas cannot afford hiring professional managers is one of the critical reasons for their typical low performance.

Models of irrigation governance

Irrigation water governance can be in the hands of different types of organizations. Among them:

- Water Users Associations (WUAs). This is a very participative solution, where farmers get self-organized. These are non-profit organizations in which all farmers have the same rights.

- Public Administration. The interface between private (farmers) and public organization is found at some point between the farmer and the Ministry. When the Government completely rules the irrigated area, performance is typically low.

- Cooperatives and other participative societies. These have been used in different parts of the world with variable results. One potential limitation is that membership is voluntary, and some farmers may not be interested in joining. This is a complex management problem. These systems require resources and bold governance to succeed.

- Local entities. In some countries public intervention in irrigation development has resulted in a strong identification between the village and irrigation governance.

- Private companies. While in some cases these companies respond to the inefficiencies of public governance, in others represent the will to extend urban water services to irrigation water governance. These models are often associated to “Build,Operate and Transfer” schemes of irrigation system development.

In general, the last decades have seen a contraction of the public system and an expansion of the private governance levels (farmers, companies…). In areas where private management was already in place, their governance has been extended upstream in the water conveyance system. Consequently, canals and reservoirs have been transferred from public to private management using a variety of legal arrangements. This is part of the maturity process of irrigation projects, although important dedicated transfer programmes have often been set in place, particularly in developing countries.

The predominance of private governance models is directly related to the empowerment of farmers and their organizations. This is in turn related to issues like: a) The wealth farmers that can individually obtain from exploiting their irrigated farms; b) The decision making capacities of farmers on financial or managerial issues; and c) The social perception of the importance of irrigated agriculture.

It is ultimately empowerment that permits farmers to develop the directive function, and to run the cycle of strategic decision making, typically divided in three phases: a) Diagnostic analysis; b) Planning; and c) Managerial improvement. In developing countries, companies have proven useful to temporarily support farmers in this process of empowerment, always under the supervision of public authorities. This stewardship should not be planned for longer periods than a decade. Cooperation between these three agents can lead to a fast development of the typical benefits of irrigation. The participation of private companies may imply higher water costs for the farmers. Governments may want to include specific financial incentives for the farmers to offset these higher costs.

Principles of irrigation governance

As a consequence of the development of the directive function, farmers' Governance has started to respond to commonly accepted management principles. Among them:

- Transparency;
- Participation;
- Water traceability in the distribution systems;
- Effectiveness;
- Monitoring and performance evaluation;
- Standardization; and
- Certification.

These principles represent a steep learning curve for most irrigation governance schemes, but at this point of time it is important to note that many irrigated areas have at least started adhering to them.

Despite the large amounts of funds devoted to irrigation development, monitoring and evaluation have only recently been introduced in many schemes worldwide. Monitoring and evaluation are critical principles to: a) Implement corrective measures in the exploitation of irrigated areas; b) ensure societal return of public funds; and: c) to avoid donor's fatigue in the context of cooperation projects.

The last point of the list, certification, needs plenty of effort before it can be successfully implemented. The most recognized international effort for the certification of management quality - ISO 9000 – has produced a list of additional principles which are completely adequate for irrigation Governance. Among them, leadership, involvement of people, continual improvement or factual approach to decision making.

Innovation: a European approach

After decades of worldwide reform in irrigation governance, progress is needed in many aspects to overcome the inheritance of the 20th century. The European Union has identified similar needs for progress in many different societal aspects. In 2010, the "Innovation Union" policy was released. This policy resulted in the inclusion of a strong Innovation component in the Rural Development Programmes stemming from the Common Agricultural Policy. As a result of this policy drive, funds will be available in Europe at the national and regional levels in the coming seven-year period to innovate in different aspects of irrigation water management, including governance. The European Agricultural Fund for Rural Development (EAFRD) has established an innovation funding line for the cooperation of academia, farmers and their organizations, private companies, associations and NGOs in order to improve water use in agriculture, including irrigation. This conference comes timely to discuss research performed on governance issues which could eventually be transformed in innovation projects funded as pilot or demonstration sites promoting new approaches to irrigation governance. This policy may result critical to shape up European farming in the 21st century, but it cannot be used elsewhere without proper consideration of local socioeconomic constraints.

Keywords: *irrigation, water, governance, association, innovation*

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INNOVATION IN WATER GOVERNANCE: WHAT IS THE FUTURE?

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Extended abstract

Dealing with current complex water challenges, like water scarcity, water pollution, water flooding, droughts, degradation of biodiversity amongst others, not only depends on the ability to develop advanced technical strategies and measures based on the latest scientific insights, but also on the ability to adjust these solutions to the demands of the complex governance context in which they have to be developed, implemented and evaluated. Therefore, water innovation is not only a technical issue but a demanding matter of governance stretching from the global to the local scale, too.

Water governance is a broad concept with many definitions. Among the others: 1) governing acts of public and private actors ultimately aiming at the realization of collective goals; 2) the communicative, juridical and economic instruments these actors use; 3) decision-making processes and interactions between these actors; and 4) the institutional systems (organizational, regulative, political, social) in which these acts, measures and processes are embedded.

It is important to note, that whilst water governance has become an increasingly popular term, it is not equivalent to water management; the water governance needs to fit into the general principles of good governance, like consensus oriented, participatory, following the rule of law, effective and efficient, accountable, transparent, responsive, equitable and inclusive (UN). Water governance is the final action in a process with multiple goals which takes into account the variety of stakeholders directly or indirectly concerned, based on the principles of the public nature of water resources, fairness, environmental quality, public health, water's social role, and security for society.

Innovation within the governance system is necessary to better deal with realizing collective goals of public interest, whereas the governance of water innovations is crucial in the future, being conscious that, on the one hand, governance system can enable, encourage and accelerate the development, implementation and marketing of water innovations and, on the other hand, governance system, can block, hinder or postpone innovations. Hence, water governance and water innovation are strictly related, facing this last the usual difficulties and barriers within the context of existing governance systems, being the following the overarching key issues to be addressed:

- Defining new forms and models of governance that connect across boundaries of policy domains and levels. An increasing number of societal domains are involved in water governance, like health, public security, waste food, energy, transport, agriculture, industry, tourism, land planning, adaptation to climate change, etc., each of them is characterized by different rules, routines and allocation of responsibilities.

- Redefining, coordinating and harmonizing existing and drawn up directives and regulatory frameworks as at EU, as at National, Regional and Local level in order to assure a more efficient and effective water management, a wide public participation and, not least, a reliable financial perspective for public and private investments in water related issues, including innovation.

- Raising public awareness. Most people do not have relevant water related problems and hence are not very supportive of investing in water issues. It is essential the definition of participatory models for water governance and water management that ensure fully sustainability and consistent integration with all other policies having sustainability development as a goal.

- Reallocating public and private responsibilities. Water management is a key public service of general interest that involves governmental responsibilities and private business. The challenge is to develop new policy guidelines and regulatory instruments that, at the same time, guarantee the water resources, as a limited asset of humankind, do not subject to market principles or competition rules and encourage the private investments in water sector.

Innovation in water governance and governance of water innovations represent very ambitious challenges on the political and societal future agendas, being numerous and hard-solving the involved barriers and bottlenecks. These last could be summarized as follows:

Innovation in water governance	**Governance of water innovation**
Lack of priority in political and societal agenda	Fragmentation of institutional roles and responsibilities in water sector
Need of long term policies and long lasting procedures	Lack of accountability and transparency in water policies
Presence of a culture of risk adversion	Need of developing and strengthening the R&D actions in the water related fields

Targets should take into account the idea of socially beneficial, environmentally responsible and economically sustainable water use, endorsing the UN Resolution[1] that recognizes water as an universal, inalienable human right and ensuring long term benefits for society while maintaining or improving biodiversity and ecological processes at the watershed level. This requires the:

- Reinforcement of European, National and Regional water policies by means of a large participatory process in which are involved policy makers, stakeholders and citizens.

- Definition of win-win synergies and links between water and water-dependent policies and economies, being necessary that water is regarded as a global priority issue.

- Definition, at watershed level, of clear and measurable efficiency targets for each area of water related activity (domestic, industrial, agricultural, fish farming, aquaculture, tourism, hydroelectric energy production, etc,).

- Introduction of a water pricing policy that, otherwise than WFD, is based, not just on the polluter-pays principle, but also, by means of an appropriate and progressive pricing, on the over-user pays principle. It has to be able to respect the national and regional prerogatives taking into account the differences in geography and climate and the related social and environmental aspects.

- Definition and adoption of a Regional and Local water management policy aiming to foster and improve the collaboration between sectors working on the same production chain and to address and solve conflicts between different water users.

Keywords: *water scarcity, pubblic and private actors, security for society, regulatory frameworks*

[1] UN Resolution A/RES/64/292 onJuly 27, 2010 *"recognises the right to safe and cleandrinking water and sanitationas a human right thatisessential for the full enjoyment of life and all human rights".*

ACTIVITIES OF PUGLIA REGION AT EU LEVEL IN THE WATER SECTOR

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Abstract

Sustainable water resources management is a priority for Puglia Region, where water scarcity, overexploitation and ever-increasing demand pose a serious issue. This is at the origin of Puglia's engagement in the water sector at EU level, a sound example of how the action undertaken at policy level can be translated into concrete opportunities of implementing EU funded projects having actual impact on the territory. In 2011 the Region's former president Nichi Vendola was rapporteur of the Opinion of the Committee of the Regions on "The Role of Regional and Local Authorities in Promoting Sustainable Water Management", endorsing some crucial principles towards sustainable water resources management:

- a clear water pricing policy could give rise to generally more efficient and effective water management, not least from a financial perspective and should be based not just on the "polluter pays principle", which already features in the WFD (2000/60), but also on the "over-user pays principle", as this is the way to restore environmental availability;

- EU policy guidelines and regulatory instruments that set out clear, precise efficiency targets for each area of activity should be adopted for the sector and defined at river basin level;

- the use of non-conventional water resources should be facilitated by promoting a culture of reuse and recycling in all areas.

These principles were taken into account by the European Commission and integrated into the Roadmap to a Resources Efficient Europe in September 2011, that reaffirms the intention to set water efficiency targets for 2020 at River Basin level and to better manage water demand through economic instruments (pricing, water allocation). Also, resource-efficiency considerations were further integrated into EU water policy, with a Blueprint to safeguard Europe's water (2012) defining a cost-effective strategy. Following the measures foreseen in the Roadmap to a Resources Efficient Europe and in the Innovation Union Flagship Initiative, the European Commission launched the European Innovation Partnership (EIP) on Water in 2012. With representatives

in both of the EIP governance bodies (Task Force and High Level Steering Group), Puglia Region has been playing a significant role in the EIP constitution process and contributed to drafting the Strategic Implementation Plan of the EIP on Water, with a particular focus on water governance. Currently Puglia Region is actively involved, together with several regional stakeholders of the scientific and business sector, in two EIP Action Groups..., namely:

- FINNOWATER, aiming to explore and develop new approaches to increase financial flows in the water sector, particularly by incentivizing innovative financial tools and\mechanisms (e.g. pre commercial procurement);

- WIRE (Water & Irrigated agriculture Resilient Europe), aiming at efficient water reuse and energy saving in integrated agricultural water management.

... and it is partner of the two following *FP7-Water Inno & Demo-2013* projects, closely related to the above mentioned Action groups:

- WATER PIPP, whose main objective is to mobilize the procurement power of public actors by transferring Innovation Oriented Public Procurement experiences to the water sector;

- DEMOWARE, aimed to mitigate the main barriers to water reuse implementation.

The experience done at EU level can be further developed by the Region in the upcoming programming period by exploring possible synergies between the several available funding sources (ERDF, EARDF, H2020, Territorial cooperation programmes, etc).

Keywords: *water governance, sustainable water management, european innovation partnership.*

WATER GOVERNANCE AND TERRITORIAL ANALYSIS: HOW TO IMPROVE IRRIGATION MANAGEMENT FROM STAKEHOLDERS' INVOLVEMENT IN DECISION-MAKING

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Abstract

In the context of increasing competition between territories, ecosystems and water demands, there is increasing emphasis on the need to organize the process of negotiation among the diversity of stakeholders through the integration of different points of view, the nature of the problem, and the promotion of mutual benefits. As a result, developers and managers of complex issues are gradually becoming interested in methods and tools that are able to integrate the diversity of interpretations of topics that cause debates and/or conflicts in time and space. Concerns about water scarcity and management have focused attention on agricultural use of water and irrigation. As the largest water-using sector worldwide, irrigation have to adapt to new demands of non-consumptive water uses. According to this, the management of irrigation has become the protagonist in a debate where society questions their own socioeconomic and environmental limits while emphasizing its multifunctional role. In other words, the juxtaposition of ancient, modernised and new irrigation projects explains the development of rural areas in parallel to their affect on ecological systems and the mobilisation of civil society. This communication maps the interaction between irrigation multi-functionality and decision-making processes for improving governance in Southern Europe hydro-social systems in order to provide insights into how these concepts are co-managed. Two approaches, the Stakeholder analysis approach and the Governance model approach are applied in combination with a new form of graphical representation to evaluate the confronted points of view between stakeholder's profiles, named Territorial Irrigation Management Analysis (TIMA). The territorial analysis of three irrigation systems in Spain, France, and Italy is exposed in order to: 1) promote a discussion about the future of multi-functional irrigated systems, 2) provide the basis for a territorial management of irrigation systems from the inclusion of civil society into decision-making processes, 3) justify the ability to propose an agreement between competing water uses and key stakeholders, 4) determine the profile of the involved stakeholders regarding their discourses, and 5) elucidate some strategies and actions for improving good governance. In countries such as Spain, France and Italy, who have a long tradition of irrigation, there are few examples of irrigation systems in which management promotes multi-functionality. The three irrigated systems presented in this paper (Segarra-Garrigues canal, Neste canal and Muzza

canal), framed much of the concerns, speeches and overlapping demands around natural resources and society nexus. Their comparison has begun from contrasting the attitudes, demands, criticisms, affinities, and ultimately the discourses defended by the diversity of selected stakeholders. The obtained results can be used by the relevant authorities to customize their interventions, knowing beforehand and in a well-structured form which are the different stakeholders' priorities and in this way establishing more effective avenues of communication. For example, promoting social learning to cope with new challenges related to water uses on each area (water availability and energy nexus, environmental flow maintenance, food security, rural development, and recreational or educational activities).

Keywords: *multi-functional irrigated systems, stakeholder, governance, territorial management, Southern Europe*

THE CONCEPT OF GROUNDWATER GOVERNANCE

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Abstract

This paper aims to develop a definition of the concept of ground water governance and to make this definition acceptable and clear for a large number of actors in the field of water governance. This definition serves as a starting point for the discussions. Since groundwater governance is the process through which these resources are managed, the basic elements of this process are the responsibility, participation, transparency and availability of information, with the need to take into account the specific characteristics of stakeholders, environments and regulations. So they are considered art of administrative procedures and decision-making between different levels - one of which may be at the global level.
This paper assumes that the state of groundwater governance is not good, needs to be improved and that we can distinguish between good governance and non-governance of groundwater. For this regional consultation the project aimed to formulate specific standards of groundwater through the views of the participants.

Keywords: *water governance actors, participation, regional consultation*

GOVERNANCE OF WATER FOR AGRICULTURE USE: THE CASE OF "TAOURIRT TAFOUGHALT RURAL DEVELOPMENT PROJECT"

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Abstract

Today, the need to improve the quality of governance has become an imperative for donors and policymakers. Indeed, this notion is at the heart of most development programs and projects, even in all the strategy documents, and is often presented either as a challenge or as a solution that would improve economic, social, political and environmental countries. Following the food security issues during the crisis in 2008 which resulted in higher international courses in basic food commodities, the ownership of the concept is no longer considered an economic issue but rather a long process which cannot be achieved without good governance and adequate tools to know the state of valuation system, strategic vision, effectiveness and efficiency of public choice, etc. The state water policies are strategic because they must allow people to feed and serve sustainable economic development. They must also take into account food security and climate change. Otherwise, the development process risks to be temporary and too expensive. These policies are still subject to climate hazards. One example are frequent droughts with consequences for human society and agricultural sector due to destruction of agricultural crops and seeds. These disasters paralyze national economies and oblige the states to seek international assistance. In some countries, these phenomena result in massive refugee flows. Faced with these challenges, the national plans of water and food resources management works are set to limit the damage and to prepare the institutions to manage this key element of sustainable development.

The objective of this paper is to present the experience in the governance of the irrigation component that was implemented during the implementation of the Taourirt Tafoughalt Rural Development Project in eastern region of Morocco. In other words, this paper aims to analyze the effectiveness, efficiency, socioeconomic impacts, sustainability and food security caused by irrigation in the area of the project. It demonstrates that using practical evaluation methods of socioeconomic development, implementing indicators and monitoring them, with modern assessment tools, will enable effective measures of the impact of public actions related to irrigation in the area of the project under climate change and its consequences such as drought in Eastern Morocco.

The project has contributed to increased access to water. Rehabilitation of existing irrigation perimeters, which exceeded the Mid Term Evaluation objectives, contributed to an increased availability of water. The efficiency of the irrigation has improved.

Irrigation contributed to an increase in yields and in gross margin of crops. High value added crops were introduced after rehabilitation of irrigation schemes. The rate of crop intensification in irrigated areas increased from 0.90 to 1.46 according to the survey conducted on the field. The creation of water users association has contributed to sustainable use and better governance of water resources.

Keywords: *governance, irrigation, food security, socioeconomic impact, droughts.*

ASSESSING THE IMPACT OF CLIMATE CHANGE ON WATER DEMAND AND SUPPLY MANAGEMENT STRATEGIES IN THE WEST BANK

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Abstract

Palestinians in the West Bank (WB) are living under unstable political conditions which directly affect water resources management. On one side, water supply is restricted since the pumping from the aquifers is controlled by Israeli authorities. On another, the water requirements are increasing due to high population rate (2.7%) and growing demand of urban and agricultural sector. As a consequence, a large portion of water is purchased from Israeli authorities mainly for potable use. The drinking water network suffers from leakage and non-authorized connections whereas irrigation is restricted mostly to greenhouses due to water shortage. This leads to unsustainable situation in the region which could be aggravated in the future. Therefore, there is a need to evaluate the present and future situation in terms of water supply and demand and to propose the mitigation/adaptation measures for ever increasing water requirements.

The study compared two scenarios, year 2010 based on the official data of the Palestinian Central Bureau of Statistics (PCBS) representing the current situation, and year 2050 based on the climate change data for A1B SRES (Special Report on Emission Scenarios) scenario produced by the ENSEMBLES project (EC-FP6-ENV). Water Evaluation and Planning System (WEAP) was used to generate different scenarios and management options for the future. The model was calibrated using the available data for current situation with the aim to achieve water balance between supply and demand for each province while taking in account both agricultural and urban sector. The agricultural water requirements were elaborated for the province-specific cropping pattern. Then, the model was calibrated fixing the irrigation inputs for each crop.

Water balance for the future was based on the assumption that water supply is fixed to the actual volumes, population growth follows the same rate as today while the agricultural water requirements depend on climate change data. The modelling results pointed out 131.2 MCM of water deficit in year 2050 mainly due to fixed water supply and high population growth. Several options to manage water deficit were elaborated including: i) increase of water pumping from the aquifer, ii) use of waste water treatment plants (WWTP) to reuse water and iii) rainwater harvesting from rooftops of greenhouses located in the West Bank, and iv) reduction of water losses in urban sector by 50%.

The increase of water pumping from the aquifers could be a solution since, according to the water balance, the annual recharge of water into the aquifers from the West Bank territory (689 MCM) is much greater than withdrawal (only 87 MCM). However, the practicability of this option is difficult due to complex political situation and impossibility to control water withdrawal from the aquifers. The use of water from WWTP could be a part of solution since additional 62.6 MCM can be produced supposing that 50% of water can be reused mainly in irrigation and in some urban uses respecting the international and Palestinian standards. Water deficit can be reduced by additional 15.5 MCM using the rainwater harvested from rooftops of greenhouses located in the West Bank. The reduction of water losses in urban water delivery network could save further 7.8 MCM. Hence, the adoption of above two options could result in the reduction of water deficit from 131.2 to 45.3 MCM which cannot fully solve the problem. Therefore, the recovery of water deficit in the future is mainly through the solution of political situation in the region.

Keywords: *water resources management, WEAP model, water balance, treated wastewater use, rooftop water harvesting, groundwater.*

SESSION:

ENVIRONMENTAL, SOCIAL AND ECONOMIC ASPECTS OF WATER MANAGEMENT

WATER SCARCITY GOVERNANCE FOR SECURING THE FUTURE

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Extended Abstract

Water scarcity is both a relative and dynamic concept, and can occur at any level of supply or demand, but it is also a social construct: its causes are all related to human interference with the water cycle. It varies over time as a result of natural hydrological variability, but, varies even more as a function of prevailing economic policy, planning and management approaches and adequacy of the actions implemented on the ground. In an increasing number of developing countries, particularly in arid and semi-arid regions, water scarcity is the result of different concatenated causes linked with the on-going climate change and including demographic pressure, urbanization, land degradation, poor management and vulnerability of existing water systems and water pollution. These factors are all putting unprecedented pressure on the limited and finite available water resources. This leads many to jump to conclusion that water crisis is inevitable.

Yet, the predictable potential water crisis can be largely avoided by adjusting the way water is managed and governed. Real changes are needed in the way in which water is governed and used if transient or long-term crises are to be averted. However, governance of water scarcity in not an easy process, but rather a complex one that still needs a long way that needs continuous refinement on the road of revision of experiences and rising problems and definition of new challenges,.

The concept of governance, as applied to water, refers to the capacity of a social system to mobilize energies, in a coherent manner, for the sustainable development of water resources (Hamdy, 2012). In order to be effective, the governance must be transparent, open, accountable, participatory, communicative, incentive based, sustainable, equitable, coherent efficient, integrative and ethical. Furthermore, it should be oriented towards the climate change mitigation and adaptation actions, the adoption of eco-efficiency concept and full consideration of water-energy-food nexus.

Governance of water scarcity often presents problems and it requires a holistic management approach which comprises: coordination of water supply and demand policies, consideration of both the quantity (including joint use of surface and underground waters) and quality of water resources, management of multiple water resources uses, coordinated and integrated management of land and energy use and water resources, management of externalities and environment protection policies.

Those approaches are the appropriate ones leading to effective water governance and they clearly indicate the very strong linkage between water governance and water resources management.
Improving water scarcity governance requires much more than efforts to increase the supply of water. Addressing the already existing water crisis requires strengthen technical capacities and national institutions and developing mechanisms to increase the transparency and accountability of public water services. It also requires increased political attention and commitments. Nowadays, the key for success is to more broadly disseminate knowledge and to bring more stakeholders into the dialogue (Hamdy 2012).
Countries seriously suffering water scarcity should work hard to reform the effective water scarcity governance by reorienting policy, reforming institutions, promoting education and awareness, increasing stakeholders' participation, and establishing international agreements and linkages to research and development (R&D). Particular efforts are needed in defining priorities, challenges and future directions for enhancement of agricultural water management since this sector uses the greatest portion of available water resources (Todorovic et al., 2015). However, in spite of the steps taken by several countries to design effective water governance there are still many factors impeding progress in water governance including unclear und overlapping responsibilities, inefficient institutions, insufficient funding, centralized decision making, limited public awareness, ineffective regulations and their enforcement, and lack of appropriate legislative instruments to support implementation (Abu-Zeid and Hamdy, 2010).
New challenges require new tools such as decentralization, strengthened technical and financial capacities of local authorities, dialogue and consensus, effective enforcement and compliance, and better water institutions organization and performance.
Good water governance shall lack legislative instruments to support its implementation. New challenges require innovative policies and tools, adoption of participatory approach, implementation of new technologies for monitoring and management of water resources, strengthened technical capacities of local authorities, dialogue and consensus effective enforcement and compliance and better water institution performance.

Keywords: *water crisis, integrated approach, participatory management, technological advancement.*

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SUSTAINABLE WATER MANAGEMENT IN GREEN ROOFS

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Abstract

In the present work, the role played by green roofs in the urban water cycle management is addressed. Primarily, the environmental, ecological and financial benefits associated with rooftop greening are described, also including reference to life cycle cost assessment. Ecosystem service provision is widely described in specific relation to the role played by water in promoting urban microclimate, air quality and resilience to climate change. Afterward, proper water management strategies are presented, with specific regard to the sustainable management of irrigation and the definition of water quality standards. The last section of the work refers to the application of alternative water sources, namely rainwater harvesting systems and greywater regeneration.

Keywords: *rooftop agriculture, green infrastructures, ecosystem service provision, urban water cycle*

MONITORING AND EVALUATION OF THE ECONOMIC AND ENVIRONMENTAL IMPACTS OF IRRIGATED AGRICULTURE IN NORTHWESTERN LIBYA

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Abstract

The present trend of continuously expanding irrigated agriculture under severely limited water resources and arid climatic conditions, as it is the case in most of the North African and Middle Eastern countries, has raised several questions related to its potential sustainability in achieving the desired objectives of economic efficiency, environmental integrity and social equity. An intensive investigation has been undertaken to assess the negative impacts of irrigated agriculture in the Northwestern region of Libya. A total irrigated area of 90 thousand hectares has been cultivated with more than 15 major crops with a total irrigation water demand of no less than 730 million cubic meters per year (m3/y). The analysis of water samples and hydrological data collected from more than 90 wells representing the whole region shows clearly that groundwater resources are depleting at an alarming and increasing rate. The negative economic and environmental impacts of this excessive groundwater depletion have been reflected in severe water level and piezometric head declines, intensive and extensive irreversible seawater intrusions, deteriorating water quality, soil salinization, exposure to nitrate pollution and reduced crop productivity. To prevent any further deterioration of the present situation , the gap between the renewable water supplies of 200 million m3/y and the agricultural water demand of 730 million m3/y must be closed through the diversion of no less than 500 million m3/y from phase two of the Man-made River Project (MRP) at the cost of 0.34-0.83 US$/m3.This huge project has been implemented with the intention of transferring the national groundwater resources that are abstracted from the regions of abundance and redistribute them among the regions of water scarcity. This water supply will have to be subsidized, however, since irrigated agriculture is unable to pay back even 10% of this cost. The other alternative is to limit the irrigation water demand to the renewable water supplies through the importation of virtual water, reducing the irrigated area and the cultivation of crops that have the highest economic crop water productivity values. The results of this investigation recommends that unless immediate measures are implemented with competent managerial skills, sustaining any reasonable level of irrigated agriculture in this region is unattainable.

Keywords: *groundwater depletion, seawater intrusion, soil salinization, unsustainable irrigation*

COMPREHENSIVE EVALUATION OF IRRIGATION SCHEMES: A CASE STUDY IN SEYHAN AND CEYHAN RIVER BASINS IN TURKEY

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Abstract

Irrigation infrastructure is one of the key factor that governments have as a tool to increase productivity and economic growth and meet its policy objectives. More specifically, irrigation is crucial for the part it plays in responding to the challenges of climate change, agricultural drought, desertification, food security, sustainability, enhancing economic development, reducing migration and enhancing social inclusion.

Çukurovawhich is the most important plain in Turkey and it is characterized by the Mediterranean ecosystem. It has the widest product range in the country's most productive farmland. 2-3 products can be grown in a year. 10% of the agricultural proceeds of Turkey has been produced in the Çukurova Region and 5% from Seyhan and Ceyhan River Basins.

This study was carried out in the Lower Seyhan and Ceyhan River Basins located in the Çukurovain southern of the Turkey. In this paper, the cumulative impact of existing irrigation projects in Seyhanand Ceyhan Basin were evaluated by considering technical, economical, social and training problems. Irrigation efficiency were computed according to the amount of water diverted into the channels and crop evapotranspiration. Physical state of the channels was examined. In order to determine judicial attitudes and behaviors of farmers related to irrigation, a survey was conducted with 253 farmers.

The findings obtained as survey results show that there are many problems related to irrigation efficiency, irrigation management, irrigation infrastructure, education and extension issues. Performance of irrigation practices, especially in the efficiency of water application is still too low, i.e. 43% in the catchment level.This is due to inadequate irrigation infrastructure and farmers lacking the management skills to manage their irrigation systems properly. 90.2% of the water are conveying by open channels. This causes high amount of evaporation and seepage losses. Regarding to irrigation management, being small areas operated by irrigation associations causes higher investment, operating and maintenance costs. While the recommended optimum area of the WUA's for the operation is about 7000 hectares, actual operated area was found 3209 hectares in the study area. Thus, water fees are rising to meet investment, maintenance and operation requirements. Irrigation extension and training services are not adequate level in the region, i.e. 83% of the farmers declared that they did not receive any irrigation training. As a result, the immediate

improvement of the irrigation infrastructure are needed besides improvement the farmers' irrigation management skills.

Keywords: *irrigation management, irrigation infrastructure, irrigation efficiency, extension, irrigation association.*

WATER AND ENERGY EFFICIENCY IN A HIGH ENVIRONMENTAL VALUE AGRICULTURAL AREA

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Abstract

One of the main water related challenges is reaching a sustainable water resources management, especially when multiple concurrent uses should be complied within specific environmental constraints.
In agriculture, the Water-Energy nexus is a valuable conceptual approach to analyse efficiency in the use of available resources, since it is crucial to optimize water consumption, especially in case of limited availability, and to limit the energy uses for reducing costs and environmental impacts.
The aim of the study is to implement an integrated methodology to support decision making about the water and energy resources allocation.
The case study is a small irrigation district, located in Apulia region (Southern Italy), relevant for its environmental value, since it is, at the same time, a renowned tourist destination, an irrigation district in which a valuable agricultural production is made (mainly grapevine and vegetables) and a complex hydrological system due to the presence of two interconnected coastal lakes (one with freshwater and one with brackish water) supplied by surface and ground water. About the lake, the former provides water mainly for agriculture and partially for human consumption, but its behaviour is strictly related by the seawater fluxes of the other.
The irrigation system is based on two identical simple schemes, both equipped with a pumping station, a pressurized conveyance pipe, and a distribution network that conveys water to single farms through rotational turns. Both of them were designed and built in the late 50s, and thus significant ageing and limited maintenance currently imply low water use efficiency and significant energy consumption.
It is worth to underline that, besides the water volumes provided by the consortium, significant water volumes are often extracted by wells, mainly depending on crop production characteristics, water availability, and water costs.
During the research activities, water withdrawals were monitored and continuously recorded during the irrigation season, and related energy consumption was estimated, in order to relate them to crop water requirements, once the crop map of the investigated area was reconstructed.
The performed data analysis, joined to the estimate of the pumping system efficiency, was successfully used for developing some potential planning scenarios of water use re-allocation.

Keywords: *water-energy nexus, agricultural sustainability, irrigation efficiency*

ECO-EFFICIENCY OF WHEAT CULTIVATION UNDER RAINFED AND IRRIGATED CONDITIONS

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Abstract

Wheat is the most widely cultivated crop in Southern Italy, mainly under rainfed conditions. Planning suitable irrigation and fertilization strategies is a crucial issue for stabilizing production and thereby enhancing socio-economic development of farm communities. However, imposed irrigation and agronomic practices can generate more pressure on water resources and environmental burdens due to additional energy and fertilizers requirements. Life cycle assessment (LCA) has been recognised as a valuable tool for assessing the environmental impacts of agricultural production and has been applied widely to winter wheat production. While LCA consider only the environmental aspects, the concept of eco-efficiency (EE) has been used as an instrument to analyze farm sustainability, i.e. to relate economic value of an activity and its impact on environment. The aim of this study is to analyze the eco-efficiency of wheat cultivation under rainfed and irrigation conditions in Apulia Region, Southern Italy. The study applies a novel approach (EcoWater, 2014) based on a combination of the Life Cycle Assessment (LCA) following ISO principles and the assessment of Life Cycle Costing (LCC). LCA followed a problem oriented approach using CML-IA baseline 2000 impact assessment method. The system boundaries were defined following the “cradle to grave” approach (i.e. from the extraction of primary resources to final use in the field). The environmental burdens covered induced emissions through the production and use of fossil fuel, production and use of fertilizers and electricity usage for irrigation. A distinction was made between impacts coming from direct use of resources on-field (foreground) and resource production processes (background). Fertilizer (direct/indirect N2O and other substances) and diesel on-field emission were estimated and converted using the IPCC Guidelines. Emission values for production of fertilizers and power inputs (i.e diesel and electricity) were retrieved from LCA databases. Total Value Added (TVA) to the product due to water use estimated as a difference between of total economic value generated from water use (substracting non-water expenses from total value of products) and total financial cost related to water supply was employed to analyse the economic performance. Eco-Efficiency Indicators (EEI) were defined as ratios of the economic performance (total value added, TVA) to the environmental performance of the system (environmental impacts). The respective assessment was performed using Systemic Environmental Analysis Tool (SEAT) and the

Economic Value Analysis Tool (EVAT) modeling tools. The analysis encompassed cause-effect relations and shows whether EE improves or declines and in which respect. Obtained results showed that optimal production with water application of 2000 m3/ha and associated agronomic practices generates on average about 55% additional emissions versus rainfed condition, with the highest impact for terrestrial eco-toxicity by 84% and the lowest for eutrophication potential by 26%. Given the additional fertilizer use for anticipating higher yield rates an increase of 11%, 16%, 17%, and 21% was estimated for climate change, eutrophication, acidification and respiratory inorganics impact categories, respectively. Impacts slightly increase with fertilization levels for human toxicity, terrestrial eco-toxicity and mineral depletion environmental categories. The economic analysis indicated that total value added of the system greatly depends upon the yields achieved, i.e. upon the level of water use. Total Value Added (TVA) to the product due to water use with a fixed market price of 250 €/tn was estimated 509 € (145.4 €/tn) and 929 € (143 €/tn) for rainfed and irrigated conditions, respectively.
In a EE assessment an economically less advantageous product/strategy can compensate for this disadvantage with a better ecological performance, and vice versa. Estimated EEI showed that the additional agricultural production achieved under full potential irrigation compensates for additional emissions for almost all categories, except for human toxicity, terrestrial eco-toxicity and mineral depletion environmental categories. Analysis demonstrate the importance of the adopted irrigation practices and show that a product under limited (deficit) irrigation might have a greater EE than a product under full irrigation. The latter becomes less eco-efficient because the environmental impacts linearly increase with the increased water supply and corresponding agronomic practices and they cannot be always compensated by any higher total value added (for example in the case of human toxicity). Nonetheless, the results confirms that under current market conditions, irrigation remains a relatively profitable activity, as well as providing greater stability of income. If however, prices for water increase, seasonal precipitation is greater than 300 mm and market price is lower then 250 € per hectare, then the relative profitability of irrigation may decrease.

Keywords: *water management, environmental performance, EcoWater Project, farm sustainability, life cycle assessment*

SUSTAINABILITY OF IRRIGATED AGRICULTURE: TURKEY AS A CASE STUDY

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Abstract

The sustainability of irrigated agriculture in many arid and semiarid areas depends on the combination of several factors, such as lack of fresh water, lack of drainage, the presence of high water tables, and salinization of soil and groundwater resources. Considering all these factors and take all the possible scenarios into account is a key for successful irrigation practices thus, favorable agricultural production. Today, current researches agree that the world has to increase food production nearly 50% by 2030 and double it by 2050. This task might be achieved through using less water with sustainable irrigation by promising protection of agricultural lands and water resources.

Under the global risk assessment of all operative factors in sustainable irrigated agriculture, the current situation needs to be well-analyzed and the feedback of the management and governance system should be evaluated for the countries to learn from each other experiences, essentially Mediterranean scale, regarding to similarity of climate and water availability in the region. Turkey is located in a semi-arid part of the world as one of the typical Mediterranean country with a limited amount of freshwater resources, having a different level of salinity and sodicity problems all over the country. The irrigated land in Turkey is 5.29 million hectares, with the majority of larger irrigation projects concentrated in the southern regions. The water is not necessarily available in the places most needed. Although water is an important political, cultural and economic issue in the country, still successful water management policies are required to meet increasing population and to heighten public awareness and knowledge for efficient water use. The aim of this work is to discuss the agricultural availability and sustainability of water in Turkey, and its political and economic aspects in agriculture, current irrigation scene over the country, development, management and governance of the irrigated agriculture over years and most importantly in the future.

Keywords: *irrigation, fresh water, sustainability, water use efficiency*

DESIGN AND PERFORMANCE ANALYSIS OF IRRIGATION NETWORKS OPERATING ON DEMAND IN DEVELOPING COUNTRIES

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Abstract

Most of the developing countries are suffering the same difficulties in the process of operating the irrigation networks. Throughout a long experience in the operation of irrigation networks in Syria, we had faced many constrains that made the operation of the irrigation networks have its own specialty.
Among these difficulties, the most important one is the relatively poor knowledge of the farmer, absence of the preserving laws and absence of the confidence between farmer and the government (utility responsible of the irrigation process).
These issues make the irrigation process randomly achieved as farmer have doubts about irrigation schedule, irrigation regime and sustainability of water resources. Therefore, farmer irrigates his land continuously whenever water is available, without any responsibility or interest of optimal irrigation schedules and water demand of crops. Farmer delivers water for his land whenever he decides without any concern of irrigation rules and he always does an aggressive action towards utility staff and other neighbor farmers. Farmer often tends to damage irrigation structure and network.
In the developing countries, this requires specialty of irrigation networks design, that takes into account the random operating, water shed, and ensuring required water and head for all hydrants.
Designing irrigation networks that work “on demand” taking into account the mentioned conditions is relatively an acceptable solution and may be the only solution for these regions.
In this paper we analyze designing and behavior of irrigation networks operating on demand in the conditions of developing countries. As well as we clarify the role of Water Use Association to enhance the farmer trust.

Keywords: *on-demand water distribution, irrigation process, irrigation networks.*

EVOLUTION OF IRRIGATION METHODS: THE CASE OF APULIA REGION

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Abstract

In this paper the evolution of irrigation methods, in relation to socio-economic and technological developments, with particular reference to the territory of the Apulian region, are reported.
The evolution of irrigation methods was determined not only by the need to reduce water consumption, but also to irrigation management at the farm level, such as:

- the gradual increase in the cost of labor;
- the growing decrease in the labor supply, even during the day.

In the fifties of the last century, irrigation was performed with gravitational methods, while in the following decades it has gone progressively towards sprinklers and low pressure localized methods. The transition from gravitational irrigation methods to sprinkler and localized low pressure methods, water distribution was also aided by the evolution of the public water supply network. In fact the water distribution network changed from the free surface (channels) to pressure pipes, and the type of water delivery, both rounded or on demand, according to the needs of the crops.
Now water networks begin to be realized equipped also with hydrants that, use magnetic cards (AcquaCard) showing contractual obligations.
Water pipe networks delivery and the prevalence of autonomous water sources (private wells) have encouraged the spread of automation in irrigation management. However, the drilling of a large number of wells, on one hand has encouraged the expansion of irrigated areas and the spread of automated irrigation methods, on the other is leading to excessive pumping of water from aquifers, resulting in their progressive salinization, as occurs along the Adriatic coast.
The evolution of irrigation methods, however, has relatively little contributed to contain specific seasonal irrigation volumes, so the future challenge will be to make the use of the current irrigation methods more efficient, through a correct definition of the irrigation variables (watering volumes and irrigation time) , in relation to:

- the hydrological characteristics of the soil;
- crops water needs;
- the criterion of maximum cost-effectiveness of water use.

Research institutions are focusing their actions on these issues and are already available information to be transferred in practice to promote water conservation.
To make those information more usable in practice, however, it would be desirable the strengthening of technical support in agriculture.

Key words: *water consumption, irrigation management*

RECOGNITION OF SALINITY SOURCES IN THE COASTAL AQUIFER, WEST OF BARDAWEIL LAKE, NORTH SINAI, EGYPT, USING HYDROGEOCHEMICAL PARAMETERS

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Abstract

Salinization of aquifer waters is a pervasive problem worldwide. Increased salinity in groundwater can come from a diverse number of sources, among them dissolution of evaporites, evapoconcentration and seawater intrusion. Additionally, as groundwater becomes more saline, geochemical evolution including exchange, precipitation and dissolution reactions can be facilitated and potentially alter water quality.
Chemical analyses of 70 groundwater points penetrating Holocene aquifer in the coastal area, west of Bardaweil Lake indicate highly saline water characterized by chloride-sodium type. Using of some significant hydrogeochemical parameters to identify the salinity sources of the investigated aquifer, indicate that:

1-Chloride-groundwater level relationship shows little to no relation, and Cl- increases as salinity increase. Moreover, chloride concentrations >200 mg/l are representing highly risk category.

2-Plotting against Cl-, the concentrations of Na, K, Ca, Mg, SO4 and HCO3 species deviate considerably from the ideal mixing curves of rainwater and seawater, reflecting rock-water interaction mainly through ion exchange phenomena.

3-The hydrochemical ratios proved mixing between fresh and saline waters, ion exchange is more active than sea water intrusion and increasing of Cl- concentration is mainly due to dissolution of evaporites.

4-Comparing visually the graphs and digrams of Piper, Durov, Schoeller and Ludwig-Lengelier showed that nearly all water samples are close to the area of saline water & sea water intrusion and about 90% of the total samples are getting worse.

5-Calcite and dolomite are the only minerals to have positive saturation indices, whereas halite and gypsum show some variation in their saturation indices.

A consecutive monitoring for groundwater levels, flow direction and carrying out the hydrochemical analyses are required for multi-years to recognize the reasons of high groundwater salinity (anthropogenic origin due to excessive groundwater use or natural phenomenon due to seawater intrusion).

Keywords: *holocene, rock-water interaction, ion exchange, mixing, saturation indices*

SOME SOCIO-ECONOMIC ASPECTS OF REPLACING SUGAR BEET INSTEAD OF SUGAR CANE

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Abstract

This study focuses on the economical, social and environmental dimensions arising from the reduced acreage planted with sugar cane, the expansion of sugar beet cultivation and crop alternative structures to identify the sugar crops and sugar production strategy in Egypt.
The economical study relied on the method of partially budget analysis for the study of the added value of sugar cane and sugar beet, compositions of alternative crop and yield per unit of water. The social study is based on questionnaires to get farmer's views on replacing sugar cane by sugar beet, the motives detailing the cultivation of sugar beet, problems facing sugar cane growers and the possibility of reducing the areas of sugar cane.
The study found that self-sufficiency in sugar amounted to about 68% in 2011 versus 59.2% in 2009. The estimated contributions of sugar cane and sugar beet were about 51.9%, 48.1% respectively of the sugar produced in 2011. The results showed that the yield/unit of water of sugar beet increases than counterpart for sugar cane for about 75% but that the cultivation of sugar beet depends on importing seeds from abroad, which is a definite constraint for the expansion of cultivation strategy mode of sugar beet. To tackle this, sugar cane is replaced by sugar beet in some different crop pattern as (beet + corn) or (beet + cotton). The yield/unit of water of these crop patterns are 903, 780 pound/1000 m3 with an increase of 25% and 8% respectively. The study also showed that reducing the area of sugar cane to 200,000 acres will provide irrigation water enough to add a new area of about 100,000 acres to the current acreage.
A strategy which depends on the expansion of sugar beet (200,000-250,000) acres in the Northern Delta region and some of the new lands, with an area of cut sugar cane to 200,000 acres and the consequences will increase the sugar self-sufficiency rate of about 70%. Taking into account the political dimension of the production of sugar as a strategy commodity needs to be the bulk locally produced to achieve food security and taking into account the social dimension of the farmers, because the cultivation of sugar cane is accompanied by the stability of economic and social conditions for farmers for a long time.
Generally, the study shows that replacing sugar cane by sugar beet in Upper Egypt will face many difficulties linked to the farmers themselves, their vision in the cultivation of beet and some economical and social aspects. It is worth-while mentioning the technical difficulties and the possibility of producing seeds of sugar beet locally. We believe that relying on sugar beet instead of sugar cane must remain in the provinces of Lower Egypt and the New Territories and the stability of the sugar cane area in Upper Egypt

Key Words: *crop patterns, yield per unit of water*

ADAPTABILITY OF EDIBLE CROPS IN MEDITERRANEAN EXTENSIVE GREEN ROOFS

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Abstract

A continuous and complex process of urbanization, with three quarters of European citizens inhabiting metropolitan areas, characterizes the current century. Cities are composed by structures and extensive interventions of anthropogenic origin, which makes them poles of environmental problems. Much of a city's surface tends to be covered with impervious surfaces that do not absorb water. Therefore, the urban environment is generally characterised by warmer climate, reduced resilience to adverse meteorological events and lower biodiversity as compared to the surrounding countryside. Furthermore, as urban population increases, the environmental costs associated to food supply (transport, storage) are exacerbated, overall mining the sustainability of the system. Urban green infrastructures have shown a great potential in improving cities sustainability and resilience, although their diffusion encounters difficulties due to the low spatial availability. Consequently, many public administrations are currently promoting the creation of greened spaces on building walls and rooftops. However, while in northern European countries extensive green roofs (where water is mainly supplied by rainfall) are widely diffused, in Mediterranean countries their adaptability is strongly dependent on the drought tolerance of the species adopted. Consistently, most Mediterranean green roofs generally host plant species with limited water requirements (e.g. Sedum), which however have no edible use, and limited ecosystem service provision potential. In the present study, the adaptability of four plant species (namely Mesembriantemum crystallinum, Chenopodium quinoa and Portulaca grandiflora, as compared to the control Sedum album) to extensive green roof was studied on an experimental rooftop garden, in the city of Bologna. Plants were grown under three different water management (providing 0, 50 and 100%, of calculated EvapoTranspiration). Beyond survival rate and biomass, measures included daily stomatal conductance cycles, as well as water relations and infrared thermal imaging, enabling to define species-specific morphological and physiological performances.

Keywords: *urban green infrastructures, drought tolerance, stomatal conductance, water use efficiency.*

IRRIGATION MANAGEMENT BY WATER USERS ASSOCIATIONS: CASE STUDIES IN THE REGIONS OF APULIA, EPIRUS AND WESTERN GREECE

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Abstract

Application of good agricultural practices is one of the key factors for achieving the objective of good ecological status of European waters under the Water Framework Directive (WFD). In Greece and Italy, FAO's Aquastat, recorded that more than 80% and 50% respectively, of the available freshwater resources are used for irrigation purposes. In Greece and Italy both central and local public authorities are responsible for the development, implementation and application control of irrigation and drainage legislative framework. The management of irrigation and drainage systems is locally done by Land Reclamation Consortia (or Water Users Associations (WUA)), mainly when surface water bodies are used as water sources, while most of drillings are private. In the frame work of IRMA project a number of tools has been developed for the improvement of irrigation efficiency in the regions of Puglia in Italy, where 400.000ha of agricultural land is equipped for irrigation and for the regions of Epirus and Western Greece in Greece, where the relevant area is 51.000 and 150.000ha respectively. One of these tools was the in depth registration of irrigation practices in the project's area. This was expected to significantly assist all relevant stakeholders to draw their future irrigation strategy. A set of questionnaires was developed to support the survey. The present study focuses on the analysis of the results regarding WUA's. This questionnaire was distributed to irrigation associations that collect the relevant information about water and energy costs, crops, economic data and main perception and issues related to climate change and environmental problems. The reality of WUAs in the study areas of Greece and Italy are presented, highlighting differences and similarities of water management in agricultural area, understanding what are the major issues related with the environmental, economic and social sustainability of agricultural livelihoods in the study area. The results of this study helps to understand the reality of study area and provide guidance to stakeholders to improve water management and be in line with WFD.

Keywords: *collective irrigation, water and energy costs, agriculture sustainability.*

SESSION:

USE OF NON-CONVENTIONAL WATER RESOURCES

WATER AND WASTEWATER RECYCLING IN THE MEDITERRANEAN AREA

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Extended abstract

Mediterranean countries are characterized by semi-arid climate, i.e. lack of natural water resources and scarce or uneven rainfall. Nevertheless, their economy is mainly based on irrigated agriculture. Moreover, in the past decades the development of local economies, population increase, and improper water management practiceshave resulted in overexploitation and/or pollution of natural water resources. Climate change also contributed to reduce water availability. For all these reasons, water shortage in Mediterranean countries has become a serious and pressing issue. In particular, water stress greatly increases during the warmer season in the coastal areas,because of conflicting requirements due to tourism and agriculture. A recent report of the EU Joint Research Centre showed that, during the period 1990-2010,in large areas of Southern Europe the number of days per year with insufficient water for vegetation growth was higher than 90(JRC, 2012).
Possible strategies for limiting water stress are: (i) transferring water from areas with higher abundance; (ii) improving water management by balancing water demand and supply; (iii) the utilization of non-conventional water sources (e.g. rain, desalinated sea/brackish water,treated wastewater), cascade use of water, drainage water recovery. Among these, treated wastewater is a largely unexploited and highly available water resource. It can be reused directly or indirectly, i.e. after replenishment of water bodies.
In the Mediterranean area, agriculture withdraws a significant share of conventional water resources: on average 65%, and over 80% in Southern and Eastern countries. Therefore treated wastewater reusefor irrigation represents a good strategy for mitigating water stress, safeguard primary sources, and supportlocal economies.Moreover, reclaimed water represents a continuous water supply and may contribute to plant fertilization. However, some obstacles still limit its utilization. Regulations sometimes inadequate (generally not adapted to local contexts) and lack of planning at the regional scale limitthe competitiveness oftreated wastewater reusein agriculture againstthe use of conventional resources. Moreover, risks soil, crops, and/or natural water resources contamination of may occurif wastewater treatment and monitoring schemesare not well designed. This risk, together with a lack of specific knowledge, negatively affects thepublic perception and may cause rejection of reuse projects. Nevertheless, where irrigation with raw or partially treated

wastewater is an established practice, there is a lower psychological resistanceto treated wastewaterreuse.
From a technological viewpoint, municipal wastewater treatment plants(WWTP) are based on the following steps:

(i) physical pre-treatments (grid, primary sedimentation, etc.), to remove larger objects, oil and sand;

(ii) biological treatment (commonly activated sludge process), to remove dissolved organic substances and, partially, nitrogen and phosphorus;

(iii) secondary sedimentation, to remove biosolids, i.e. thebiomass grown in the biological process.

The effluent of the secondary sedimentation (called secondary effluent or secondary settled wastewater) still contains substances that may be harmful for irrigation purposes. Pathogen microorganisms may cause hygienic problems for farmers and final users. Suspended solids (SS), if present at high concentrations,may clog pipes and accumulate in soil. High nutrientconcentrations (N and P) may cause eutrophication of storage basins. Metals and organic micropollutants may accumulate in crops and move to the food chain.
A tertiary treatment scheme composed offiltration(sand or surface) and disinfection processesallows forthe removal of suspended solids and microorganisms.To enhancesolids removal, filtration may be preceded by coagulation-flocculation,and sedimentation.If filtration is operated by membranes, a partial disinfection (depending on membrane pore size) and the complete removal of SS are achieved, favouring the use of UV disinfection. As an alternative to tertiary membrane filtration, a simplified scheme that integrates membrane filtration and biological process in one single reactor can be adopted (MBR, Membrane BioReactor). However, due to installation costs and maintenance requirements (periodical check and cleaning), membrane technologies are sometimes considered not competitive for irrigation purposesin Mediterranean countries.A low cost alternative option is represented by constructed wetlands. They allow for complete nutrients removal and partial removal of solids, toxic compounds, and microbiological contamination.However, to meet local standards for reuse in agriculture, further treatments may be required(especially disinfection).
Regulatory aspects play an important role in wastewater reuse in agriculture, since they influence treatment costs (directly linked to standard limits) and public perception. Regulations governing treated wastewater reuse differ significantly among Mediterranean countries.In particular, while all European countries adopted specific regulations, some Asian and African countries prohibited reuse or have no specificregulations (Kellis et al., 2013).
The interest of scientific community and European Governments for wastewater reuse has increasedsignificantly in the last 15 years, as shown by the high number of EU funded research project in this field. In terms of full scale installations, several WWTPs are currently supplying water for direct or indirect reuse in agriculture (e.g. Shafdan in Israel; Fasano in Italy; Limassol in Cyprus) or for urban reuse (Sabadell

in Spain). However, the full potential of wastewater reuse in the Mediterranean area is still unexploited. In order to achieve this objective, wastewater treatment for reuse should be considered as a production process where sewage is the raw material and the produced water is the final marketable product. Moreover, the definition of quality standards should take into account that different produced water qualities should be dedicated to different uses, also considering the cost of treatment.

Keywords: *wastewater, reuse, irrigation, mediterranean countries.*

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YIELD RESPONSE OF QUINOA TO IRRIGATION WITH DRAINAGE WATER AND PLANTING TIMES IN THE MEDITERRANEAN REGION

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Abstract

In regions where irrigation water supplies are limited, drainage water can be used to supplement them. However, the quality of the drainage water determines which crops can be irrigated. Field experiments were carried out during the quinoa growing season of 2012 in Tarsus, Turkey in order to evaluate the effect of irrigation using drainage water and planting dates on yield and yield components. The experiment was laid out using two line-source irrigation systems which allows a gradual variation of irrigation, in direction at right angle to the source. A total of four irrigation levels (I1: full irrigation; I2 through I4: deficit irrigation levels) and a rain-fed treatment were considered. Quinoa (Chenopodium quinoa Willd.) 'Titicaca' variety was planted on April 11, 2012 as for normal planting and April 30, 2012 for late planting. Quinoa seedlings were transplanted to experimental plots. The quality of drainage water varied from a low of 0.57 dS m-1 in June to 1.68 dS m-1 in April. Seasonal water use of quinoa varied from 208 mm in I5 in the late planting and 473 mm in I1 treatment plots in the late planting times. Evapotranspiration was significantly influenced by irrigation levels. Irrigation levels significantly ($P \leq 0.05$) affected quinoa grain yield. In general, quinoa grain yields in the normal planting plots were higher than late planting plots. Highest grain yield of 63.80 g per plant was obtained from treatment plots adjacent to the line-source in I1 treatment in the normal planting condition. For the late planting, highest grain yield was obtained in I1 treatment plots as 26.10 g per plant. The results showed that irrigation levels and planting times produced significantly different yield and yield attributes. Normal planting time was superior to late planting. Soil salinity in the top soil layer (30 cm) increased to 1.46 dS m-1 at harvest from 1.15 dS m-1 at sowing. Soil salinity decreased with increasing depth. The winter rainfalls (annual rainfall is 650 mm; and 65 % of it falls during winter period) leached the salts out of the crop root-zone prior to the new growing season. Thus, the results revealed that drainage water can be used for irrigation of wheat and quinoa under water shortage conditions.

Keywords: *drainage water reuse, water use efficiency, planting times, soil salinity*

COST-BENEFIT ANALYSIS OF WASTEWATER REUSE

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Abstract

Heavy metals occur naturally as chemical elements in the earth's crust and surface soils in varying concentrations and they readily accumulate in toxic levels. Most of the point sources of heavy metal pollutants are industrial activities and wastes. Heavy metals are transported by runoff water and contaminated water sources including irrigation reservoirs, channels, etc. The release of large quantities of heavy metals has resulted in their accumulation in food chain, and thus may pose a significant danger to human health. Some of the heavy metals, such us Ni and Cr, exist in irrigation water, are toxic and carcinogenic and cause a serious threat to the human health, thus public awareness has been raised on the harmful potential of heavy metals. Cross-contamination of edible parts of vegetables and medicinal plants by heavy metals is an emerging hazard for human nutrition as there are a lot of research proofs linking food chain and heavy metals uptake. European Commission has already set maximum levels for Cr and Ni in water for human consumption (Council Directive 98/83/EC) but not in foodstuffs (Commission Regulation EC 1881/2006) and there is a legal gap about these two emerging hazards in food chain. For these purposes, pot experiments have been conducted in order to answer especially if Cr and Ni content of irrigation water can cross-contaminate shoots and roots of Lavender (Lavandula angustifolia) and Sweet bush basil (Ocimum basilicum L.) cultivated in a soil never previously polluted with heavy metals. The research was targeted to study the concentration of Nickelium (Ni) and Chromium (Cr) in shoots and roots of these plants as affected by different applications of Ni and Cr to the soil through drip irrigation water. The pot experiment for each plant was arranged in a complete block design with five treatments and five replicates for each treatment, with a total of 25 pots for each element. Nickelium was applied as Nickel(II) Chloride Hexahydrate (NiCl2 6H20) in amounts of 0, 5, 10, 20 and 40 mg Ni L-1 and Chromium(VI) was applied as Potassium Dichromate (K2Cr2O7) in amounts of 0, 5, 10, 20 and 40 mg Cr L-1. The experiment was conducted in the spring of 2014, started on 14th of May and ended on 3rd of July with harvesting (eight weeks Results show that plant absorbs Ni and Cr in considerable levels. Ni and Cr (as total Ni and Cr) can pass directly through irrigation water to shoots and roots of Lavender (Lavandula angustifolia) and Sweet bush basil (Ocimum basilicum L.) depending on the irrigation water concentration of these heavy metals. Lavender and Sweet bush basil, cultivated in a soil never

previously polluted with heavy metals and irrigated for the first time with water at different Ni(II) and Cr(IV) concentrations that practically can be found in nature, can be cross contaminated as an effect of the irrigation water Ni and Cr content. The hazard for the transfer of these heavy metals in food chain is evident.

Keywords: *heavy metals uptake, irrigation water*

HEAVY METALS UPTAKES THROUGH IRRIGATION: A CASE STUDY OF NICKELIUM (Ni) AND CHROMIUM (Cr) IN LAVENDER (*LAVANDULA ANGUSTIFOLIA*) AND SWEET BUSH BASIL (*OCIMUM BASILICUM L.*) IN A SOIL NEVER PREVIOUSLY POLLUTED WITH HEAVY METALS

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Abstract

Heavy metals occur naturally as chemical elements in the earth's crust and surface soils in varying concentrations and they readily accumulate in toxic levels. Most of the point sources of heavy metal pollutants are industrial activities and wastes. Heavy metals are transported by runoff water and contaminated water sources including irrigation reservoirs, channels, etc. The release of large quantities of heavy metals has resulted in their accumulation in food chain, and thus may pose a significant danger to human health. Some of the heavy metals, such us Ni and Cr, exist in irrigation water, are toxic and carcinogenic and cause a serious threat to the human health, thus public awareness has been raised on the harmful potential of heavy metals. Cross-contamination of edible parts of vegetables and medicinal plants by heavy metals is an emerging hazard for human nutrition as there are a lot of research proofs linking food chain and heavy metals uptake. European Commission has already set maximum levels for Cr and Ni in water for human consumption (Council Directive 98/83/EC) but not in foodstuffs (Commission Regulation EC 1881/2006) and there is a legal gap about these two emerging hazards in food chain. For these purposes, pot experiments have been conducted in order to answer especially if Cr and Ni content of irrigation water can cross-contaminate shoots and roots of Lavender (Lavandula angustifolia) and Sweet bush basil (Ocimum basilicum L.) cultivated in a soil never previously polluted with heavy metals. The research was targeted to study the concentration of Nickelium (Ni) and Chromium (Cr) in shoots and roots of these plants as affected by different applications of Ni and Cr to the soil through drip irrigation water. The pot experiment for each plant was arranged in a complete block design with five treatments and five replicates for each treatment, with a total of 25 pots for each element. Nickelium was applied as Nickel(II) Chloride Hexahydrate (NiCl2 6H20) in amounts of 0, 5, 10, 20 and 40 mg Ni L-1 and Chromium(VI) was applied as Potassium Dichromate (K2Cr2O7) in amounts of 0, 5, 10, 20 and 40 mg Cr L-1. The experiment was conducted in the spring of 2014, started on 14th of May and ended on 3rd of July with harvesting (eight weeks Results show that plant absorbs Ni and Cr in considerable levels. Ni and Cr (as total Ni and Cr) can pass directly through

irrigation water to shoots and roots of Lavender (*Lavandula angustifolia*) and Sweet bush basil (*Ocimum basilicum L.*) depending on the irrigation water concentration of these heavy metals. Lavender and Sweet bush basil, cultivated in a soil never previously polluted with heavy metals and irrigated for the first time with water at different Ni(II) and Cr(IV) concentrations that practically can be found in nature, can be cross contaminated as an effect of the irrigation water Ni and Cr content. The hazard for the transfer of these heavy metals in food chain is evident.

Keywords: *heavy metals uptake, irrigation water*

EFFECT OF TREATED URBAN WASTE WATER IRRIGATION ON TWO SOILS (CLAY AND SANDY) AND TWO CROPS (TOMATO AND BEAN) IN SOUTHERN ITALY

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Abstract

Unconventional waters represent a supplemental resource in agriculture, since they increase the availability of irrigation water and reduce the gap between supply and demand of fresh water in semi-arid environments.
In this study, realized in Southern Italy, the effects of irrigation with treated urban waste-water (UWW) on two crops (tomato and bean) grown on two soils (clay and sandy) are reported. The main objectives of this research included: (i) the variation in the circulating solution along the soil profile; (ii) the composition of drained waters; (iii) the yield of the bean and tomato crops.
The experiment was conducted in aboveground lysimeters filled with two soils (clay and sandy) and equipped with porous cups at 4 depths (30-60-90-120 cm). Two crops were cultivated: bean "Lingua di fuoco" in 2005 and tomato "HF 2776" in 2006. The lysimeter set-up was placed at CREA-SCA experimental farm in Rutigliano (BA), Southern Italy. The treatments (4-time replicated) were arranged in a split-plot experimental design with soil (sandy vs. clay) in the main plot, and the quality of the irrigation water in the sub-plot (T0=100% groundwater; T50=50% UWW and 50% groundwater; T75=75% UWW and 25% groundwater; T100=100% UWW). During the crop cycle, from each lysimeter, weekly samples of circulating solution (at different depths) and samples of drained water were collected. Water samples were analyzed for quantifying pH, electrical conductivity, chlorides, sulfates and nitrates. At harvest of each crop, the biometric and productive parameters were determined.
In the case of bean, the seed yield was less in sandy soil (177 g plant-1) than in clay soil (298 g plant-1), the chlorides concentration and electrical conductivity were higher in the deeper soil layers, not colonized by the root system (>0.60 m).
In the case of tomato, the fruit yield was 4.5 kg m-2 in the sandy soil and 5.6 kg m-2 in the clay soil, chlorides concentration (from 170 to 590 mg L-1 in clay soil and from 140 to 910 mg L-1 in sandy soil) and electrical conductivity (from 0.9 to 2.8 dS m-1 in clay soil and from 0.6 to 2.8 dS m-1 in sandy soil) varied accordingly the amount of UWW in the irrigation treatments.
In conclusion, the treated urban waste water (UWW) can be used for irrigating, without compromising the production of bean and tomato. The qualitative composition of the drainage waters does not cause concern for the pH and nitrates, while a threshold level must be carefully considered for EC and Cl-, especially when UWW is used without other types of irrigation water.

Keywords: *lysimeters, circulating solution, drainage wate*r

ECONOMIC CONSIDERATIONS FOR MAIZE FERTIGATION WITH TREATED OLIVE MILL WASTEWATER

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Abstract

Olive mill wastewater (OMWW) is a by-product of the olive oil extraction process, characterised by high polluting load and polyphenols content. The treatment of OMWW, using microfiltration and XAD4 resin, results in recovery of polyphenols, which may then be utilized in the pharmaceutical, cosmetics and food industry, and also in an effluent (treated OMWW), friendlier to the environment than the initial OMWW, due to its decreased organic load and phytotoxic properties.
The effects of the treated OMWW (T-OMWW) application on maize kernel yield and quality, and soil quality were investigated through a two-year field experiment. Treated OMWW was applied by drip irrigation to maize cultivation on a clay loam soil using two rates of 25 and 50 Mg ha-1 year-1, with the addition of mineral fertilization. Furthermore, a treatment of only T-OMWW applied at the rate of 50 Mg ha-1 year-1, and an only mineral fertilization treatment were used. The four treatments were replicated four times. The experimental results of both years showed that there was no significant difference in crop yield and quality between mineral fertilization and T-OMWW application, hence indicating that T-OMWW could fully substitute mineral fertilization under the conditions of our study. A non-significant trend for better results with the combined application of T-OMWW at 25 Mg ha-1 with mineral fertilization in comparison to T-OMWW application at 50 Mg ha-1 was observed.
Based on the experimental results, an economic analysis was undertaken in order to evaluate the economic implications of T-OMWW application by drip irrigation to maize production. Three scenarios were investigated: a) mineral fertilization only, b) T-OMWW application at the rate of 50 Mg ha-1 year-1 only, and c) T-OMWW application at the rate of 25 Mg ha-1 year-1 combined with reduced mineral fertilization. Mineral fertilization involved the cost of buying the mineral fertilizers used in our study. T-OMWW utilization involved no buying cost (it was assumed that T-OMWW was provided with no charge by the olive mill). Instead it involved the transportation cost from the olive mill to the field. The transportation cost was determined considering a distance up to 100 km between the olive mill and the farm, and also two transport options: a) using the available farm tractor and tanker, and b) hiring a liquid transport company. The application cost of T-OMWW and mineral fertilization was considered equal, since the application of both fertilizers was carried out using the drip irrigation system.

The cost analysis showed that maize fertigation with T-OMWW at the rate of 50 Mg ha-1 year-1 was the least expensive of the three scenarios investigated, irrespective of the distance between the olive mill and the farm. The use of the farm tractor and tanker for the T-OMWW transportation was more cost effective than hiring a liquid transport company, for distance up to approximately 25 km. For greater distance, hiring a liquid transport company was more economical. The mineral fertilization only scenario was similar, from an economical point of view, to the combined T-OMWW and reduced mineral fertilization scenario up to a distance of 50 km.

Keywords: *microfiltration, XAD4 resin, liquid fertilizer, transport cost, maize kernel yield*

This research has been co-financed by the European Union (European Social Fund - ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: ARCHIMEDES III. Investing in knowledge society through the European Social Fund.

MODELLING RAINWATER HARVESTING TO ASSESS POTENTIAL WATER SAVINGS FOR URBAN FOOD

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Abstract

In many metropolitan areas of the Global North, food cultivation in vacant spaces or in private gardens is a continuously growing trend. Irrigation is the main input in this production process calling for considerations about available water resources, especially in Mediterranean cities where water shortage can be common. Therefore, planning and managing properly urban water resources can be relevant, also for counterbalancing future Climate Change impacts. Devising means for water saving and assessing the potential of alternative sources, such as collecting rainwater, could be a viable option.
In this paper, a dimensionless methodology to evaluate water saving benefits of Rain Water Harvesting (RWH) systems for multiple use in residential buildings is presented.
The methodology is based on the continuous water balance simulation of the rainwater storage tank using long-term series of daily precipitation as input for the tank model.
The harvesting scheme assumes the collection and storage of rainwater from the building rooftop, for indoor toilet flushing and residential garden irrigation uses as tank output.
Demand for rainwater for the two uses is evaluated based on data from previous analysis (for WC demand) and on results of long-term soil water balance (for garden irrigation) for a reference crop.
The methodology provides dimensionless graphs and relationships to estimate the water saving efficiency of the RWH system for the considered indoor and outdoor uses.
Evaluation on the potential of the RWH system for saving potable water from mains was performed in the city of Rome by simulations on 2,600 residential food gardens. Results indicate that, for the practical application range of storage tank sizes, water saving may range between 25-60% and between 5-30% for toilet flushing and for garden irrigation, respectively.

Keywords: *domestic rainwater harvesting, tank water balance simulation, urban agriculture, Rome.*

DEVELOPMENT AND EVALUATION OF THE USE OF BRACKISH GROUNDWATER IN INTEGRATED AQUA-AGRICULTURE SYSTEMS IN NEW LAND IN EGYPT

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Abstract

Fish farming has shown tremendous growth during the last decade in Egypt and has turned the country into a world-player in this field. Fresh water use for fish production is not allowed in Egypt and farmers use drainage water or groundwater for it. Also, brackish water is used for agriculture and for fish production. The combination of fish farming with agriculture using brackish water is a high potential future economic activity in Egypt and other countries of the Middle East. This combination allows reuse of water and nutrients and has potential for economic and environmental savings. This study aims to develop and evaluate a prototype of using brackish groundwater for integrated food systems in new land, which represents sandy soils in Egypt's desert, and to identify a number of crops that can be grown with brackish groundwater in the desert environment, as well as the feasibility of the integration of fish growing with agriculture using brackish groundwater. For this purpose several field experiment were conducted at Wadi El-Natroun Experiment Station. The preliminary findings recommended that field practices by using frequent irrigations will reduce the effective concentration of toxic constituents and therefore their adverse effect. Application of amendments, such as soluble calcium salts or sulphuric acid can therefore greatly reduce the toxicity hazard due to excess sodium. Blending of water supplies, planting less sensitive crops, improving drainage conditions through profile modification, use of fertilizers in optimum doses to obtain otherwise vigorously growing plants etc. are some of the other practices that will help overcome toxicity problems. In addition, some important management practices should also be applied: while it is important to avoid over-irrigation, frequent irrigation is necessary to maintain moisture at 75 percent of field capacity. Our preliminary assessment of the economic feasibility indicates a break-even of the investment costs of about 5 to 6 years assuming the culture of Tilapia. We concluded that the integrated aqua-agriculture approach certainly has a future in Egypt and others countries of the Middle East and seems to be a good business proposal. Many uncertainties and questions still remain to be answered.

Keywords: *fish farming technologies, aquaculture, halophytes, red tilapia, quinoa*

EFFECTS OF RECYCLED AND GREY WATER ON THE DEVELOPMENT AND STATUS OF PLANTS IN URBAN LANDSCAPES

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Abstract

Alternative water sources have been successfully implemented for irrigation purposes in many countries world widely in the framework of water resources conservation strategies. Although Europe is not considered to be an arid continent, countries around the Mediterranean basin experience frequently water scarcity phenomena attributed to unequal distribution of precipitation during the year and large withdrawals by the agricultural sector. Landscape irrigation also requires considerable amounts of water as urbanised areas are growing and tourism sector is expanding around the basin. A field study was conducted at the Technological Educational Institute of Epirus (TEIEP, Arta, Greece) from May to October 2014 in order to assess the effects of irrigation using alternative water sources on the growth and status of plant species frequently encountered in landscaping projects at North and Western Greece. Irrigation with tertiary treated wastewater provided by the Municipal Sewage Treatment Plant and grey water captured from actual cleaning activities in TEIEP's facilities were applied to tall fescue (Festuca arudinacea) and six shrub species, namely: Abelia chinensis, Ligustrum japonicum, Photinia serrulata, Viburnum tinus, Pittosporum tobira and Thuja occidentalis. Irrigation with tap water provided by the municipal potable water supply network was considered to be the reference treatment. Quantitative and qualitative characteristics were evaluated by a series of measurements which included: turfgrass fresh and dry cutting weighs, solar radiation reflectance by the turfgrass canopy, fresh and dry weighs of turfgrass roots, shrub growth parameters (including height, stem diameter, growth index, fresh and dry weighs of shrub roots), chemical analysis of plants' roots and leaves, optical evaluation of shrubs, soil EC and pH. The results revealed that in overall recycled and grey water did not have any evident reverse effect on all plant species status, although there have been pointed out some variations in quantitative or qualitative characteristics when compared to tap water irrigation treatments. Turfgrass irrigated using recycled water presented no difference in growth development compared to the reference turfgrass. The grey water treatment, although that it exhibited the lowest growth rate, did not demonstrate any difference in qualitative terms as determined by the solar radiation reflectance analysis. Growth development of shrub species treated with recycled water was not significantly affected apart from Pittosporum tobiris plants. Optical evaluation findings differentiated some of the

species (Thuja occidentalis, Pittosporum tobira) indicating that shrubs irrigated with either recycled or grey water exhibited lower quality performance when compared to reference treatment. There has been observed an increase in soil EC and pH values in recycled and grey water treatments, although these values did not exceed acceptable limits. In conclusion the study's findings can support the effort of utilization the assessed alternative water resources as supplement or even when possible as complete substitute of freshwater for landscape irrigation purposes since no evident quantitative or qualitative adverse effects have been observed.

Keywords: *landscape irrigation, alternative water resources, canopy reflectance indices*

IRRIGATION WITH MUNICIPAL WASTEWATER AFFECTS SOIL CHEMICAL CHARACTERISTICS AND NUTRIENT UPTAKE IN A NECTARINE ORCHARD

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Abstract

This research was performed in order to assess the agronomical and environmental effects of different treated municipal wastewater sources (TMW) in agriculture. In particular, it was evaluated the impact of different TMW on the water-soil-crop system in a commercial nectarine orchard (Southern Italy). Four irrigation water sources were used: a secondary-treated municipal wastewater (SW), a wastewater made by a simplified lagoon treatment pilot plant (LW), a tertiary-treated wastewater (TW) and finally a fresh water source (FW). Overall, plots irrigated with municipal wastewaters showed higher soil pH but not greater soil salinity. Plots irrigated with LW and SW showed an increase of P Olsen. The same behavior was observed for Ca concentration in plots irrigated with TW. The higher pH decreased Fe and Mn soil availability. In FW, LW and SW-treated plots, where the solution alkalinity was slightly lower, this effect was less evident. A tendency to decrease the amount of calcium in fruit tissue of trees irrigated with municipal wastewaters, with a significantly lower value for SW in comparison to FW is highlighted. Accordingly, the highest concentrations of Cu, Fe and Zn in fruit tissues were observed in plots irrigated with FW, whereas lower values were observed for plots irrigated with all municipal wastewaters, where soil pH was higher. The reuse of municipal wastewaters, regardless of treatments, could create nutritional disorders due to complex interaction between soil and water sources. This horticultural practice needs a constant monitoring of water source characteristics throughout the irrigation season.

Keywords: *prunus persica (l.) batsch, water recycling, plant nutritional status, water- soil-crop interactions*

EU-INDIA R&D PROJECT WATER4CROPS. ACTIVITIES ABOUT IMPROVING WATER USE EFFICIENCY THROUGH AGRONOMICS, PLANT BREEDING AND LOCALLY ADAPTED IRRIGATION TECHNOLOGIES AND TECHNIQUES

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Abstract

Many regions of the world are approaching, or have already reached, the limits of their available water supplies. In addition, the world's population is estimated to increase dramatically from 7 billion at present to 9 billion by the year 2050 and this growth has to be matched with the increased food and water demand and subsequently, bigger wastewater volume.
Climate changes will contribute to exacerbate such already critical situation. Not only Mediterranean and arid and semi-arid regions will suffer higher temperature and reduced precipitation, with more severe drought periods, but also temperate and humid areas in northern Europe are expected to cope with possible increasing water scarcity.
Within such a scenario, since irrigated agriculture is the main consumer of fresh water there is a need to acquire further knowledge on how to adapt to this serious situation. For sure, implementing water saving agricultural best practices, increasing water use efficiency, growing less water demanding crops, exploiting alternative water resources, e.g. reusing wastewater, will contribute to mitigate the problem.
In particular, as for wastewater reuse, it should be not only considered as an instrument for producing alternative water resources, but also as a central source for recycling high value elements and input for integrated bio-refinery processes and this is exactly in line with the rationale behind the concept of Green Economy which is a top priority for Europe as well as India.
In such a context, on 2012, the European Commission through its 7th Framework Programme and the Indian Government through its Department of BioTechnology separately co-funded with six and three millions of euros respectively two coordinated "twin" projects titled "Integrating biotreated wastewater reuse with enhanced water use efficiency to support the Green Economy in Europe and India" whose joint acronym is "Water4Crops" (W4Cs). The main objectives of both projects, i.e.:

- developing innovative biotechnological wastewater treatments, even based on plant-systems, for boosting wastewater reuse in agriculture;

- improving water use efficiency through agronomics, plant breeding and locally adapted irrigation technologies and techniques.

are synergistically aimed at enhancing Green Economy in Europe and India
To achieve such a goal, Water4Crops has set up an original modular biotechnological process aimed at improving water use efficiency and exploiting wastewater as an alternative water resource and as a source of organic carbon and nutrients. This leads to an innovative triangle producing and/or recovering: extra added value compounds (organic acids, alcohols, PHA, ...) and nutrients from agrofood industry or municipal wastewaters; additional water resources necessary to increase crop yield; and energy, through a cascade approach. In practice, while nutrients and treated wastewater go back to the land creating opportunities to increase crops yields and allowing new crops to grow even spreading harvest periods and processing times, new crops and greater yields promote more food processing and biorefinery activities. Of course, the co-creation of these new products combinations will lead to enhanced business opportunities.
In particular the objectives and first results of the WP3 "Efficient water use in Irrigated Agriculture" will be showed:

- Adapt advanced water saving irrigation technologies and strategies to water use and reuse at field scale
- Provide low and high tech, multi-functional solution tailored for field scale agriculture
- Further develop, test and adapt actual evapotranspiration, Eta and soil water sensor technologies relevant for treated waste water, TWW reuse problems
- Increase water use efficiency and productivity as a step forward towards a better local green economy
- Modelling the impact of the proposed irrigation technologies and strategies on crop, soil and groundwater at field scale
- Assessment and benchmarking of the opportunities of water saving at field and basin scale

Keywords: *climate changes, agriculture, waste water, irrigation*

ASSESSMENT OF HYDROGEOCHEMICAL PROCESSES AFFECTING GROUNDWATER QUALITY IN THE AREA BETWEEN SAFAGA AND EL-QUESEIR, EASTERN DESERT, EGYPT

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Abstract

This article is dealing with the main hydrogeochemical processes affecting groundwater composition in Safaga-Quseir district. The study area extends parallel to the western coast of the Red Sea for about 120 km with a width varying between 40 and 80 km inland wards. Five water-bearing formations with different potentialities are recognized; these are Quaternary alluvial, Middle Miocene sandstone, Oligocene sandstone, Cretaceous limestone and Pre-Cambrian fractured basement rocks. To achieve the main target of this study, 19 groundwater samples in addition to 17 rock samples were collected and chemically analyzed. The hydrochemical results showed that the groundwater salinity varies among fresh (5%), brackish (42%) & saline (53%) and the main water chemical type is Cl–Na (79%). Water salinity, water chemical types as well as the main hypothetical salts reflected the impact of marine deposits' dissolution on groundwater composition.

Results showed that carbonate weathering, leaching & dissolution, ion exchange in addition to the oxidation/reduction are the main hydrogeochemical processes affecting groundwater quality in the study area.

Carbonate weathering is the dominant and more significant than silicate weathering. Leaching and dissolution could be studied through the determination of multiple ionic ratios (Gibbs & scatter diagrams), saturation indices and water extracts. Gibbs diagram indicated that, the groundwater composition in the investigated area is mainly controlled by water-rock interaction (chemical weathering of rock-forming minerals) beside a little contribution of evaporation factor, which increases Na and Cl ions and in turn increases groundwater salinity (especially in shallow hand dug wells). The scatter diagrams showed more leaching and dissolution of marine deposits in the Quaternary alluvial, Oligocene sandstone and Cretaceous limestone aquifers, dissolution of soda-rich marine deposits in Middle Miocene sandstone aquifer, dissolution of terrestrial salts in Pre-Cambrian fractured basement aquifer. Saturation indices indicated that the majority of groundwater is super-saturated with calcite and dolomite. Water extracts revealed that the groundwater in the alluvial and carbonate aquifers are extensively affected by water-rock interaction. Ion exchange process showed the exchange of Na and K from water with Ca and Mg from the rocks in 90% of water samples. Oxidation/reduction process indicated the reduction of sulfate into sulfur in 90% of groundwater samples due to high concentration of chloride. Finally, some recommendations are given to overcome both high water salinity and water shortage in the investigated area.

Keywords: *quseir-safaga, groundwater chemistry, water-rock interaction, hydrogeochemical processes.*

EVALUATION OF ANAEROBIC DIGESTATES LIQUID FRACTION FROM POSIDONIA RESIDUES AS NUTRIENT SOLUTION FOR LETTUCE SEEDLING PRODUCTION

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Abstract

Anaerobic digestion is a technique of growing interest as a promising option for waste disposal and green energy production. The anaerobic effluents (digestate) are a mixture of water (about 95 %) and partially degraded organic matter. Afterwards separation of the two components (liquid and solid), the inorganic ions with a fertilizer value are concentrated mainly in the liquid one.
The main limitation to their agricultural use could be the sodium chloride content derived from the initial matrices and the potential phytotoxicity originated from partially decomposed organic matter.
In this study the main agrochemical characteristics and the phytotoxicity of eight digestates (derived from co-digestion of posidonia residues with different pre-treatments - grinding, washing and autoclave treatments - and a mixture of urban sludges and organic wastes) were evaluated in order to assess their potential use as a source of water and nutrient elements in vegetable seedling production.
Lettuce (Lactuca sativa L. var. Ezra) seedlings for transplant were produced on peat based substrate. Digestates liquid fraction (LD), obtained after centrifugation, was used to integrate the nutrient solution at rate of 1:10 v/v; a standard nutrient solution for lettuce seedling cultivation was used as a control (NS).
Main chemical properties (pH, EC, inorganic ions content) of LD, shoot and root fresh and dry weight, leaf area, root morphology, root/shoot ratio were determined.
Different content of Cl- and Na+ were found in LD in relation to the posidonia residues pre-treatment; moreover LD contained in general high concentration of NH4+, K2+, Mg2+ and Ca2+. Plants cultivated using LD showed a root/shoot ratio (important to ensure good engraftment after transplanting) not significally different from plants grown with NS. The use of LD produced a fresh water saving of 10% and the reduction of mineral fertilizers use.
The liquid fraction of digestates could be a good source of macro nutrients and water, and first results indicate that could be re-utilized in relation to its salts content as nutrient solution for lettuce seedling production and likely in soilless cultivation systems.

Keyword: *vegetables, inorganic ions, lettuce, water and nutrient saving.*

This research has been conducted in the framework of the Apulia Region project "Trattamento e riuso sul territorio di BIOmasse provenienti da POSidonia spiaggiata (BIO.POS.)" (P.O. PUGLIA FESR 2007-2013 Linea 1.2 - Azione 1.2.4).

CONSTRUCTED WETLANDS

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Abstract

Due to the important and great request of water in the world and insufficient quantities of the water, search for unconventional resources is increasing. The most important resource is wastewater reuse, especially for agriculture sector which, due to great consumption of water, employs also the relatively low water quality. This does not mean that agriculture can accept any quality of water, but the irrigation water should meet the standards adopted from national and world organizations for health, environment and agriculture.
We are discussing in this paper an experimental method for treatment called “Wetlands” and an appraisal of design, efficiency and economy.
The work included eight ponds, three were planted with common reeds, three with Vetiver grass, one was unplanted (control pond) and one as a collector.
In the efficiency analysis, the monitoring parameters included: conductivity, pH, COD, BOD5 and P,N,K and trace elements.
The economic analysis showed that constructed Wetlands are cheaper solution than most other treatment methods and that some advantages can be achieved from wastewater reuse.

Keywords: *constructed wetlands, wastewater reuse, treatment methods.*

MICROBIAL QUALITY OF TREATED WASTEWATER FOR AGRICULTURAL REUSE IN APULIA REGION (ITALY)

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Abstract

In recent years, irrigation with treated municipal wastewater has become a very common practice in many countries worldwide, due to the water shortening and to the necessity of assuring environment protection. In fact, in many water-scarce countries, wastewater is widely used for vegetable irrigation. Many studies reported that food crops for raw consumption could be successfully irrigated with reclaimed wastewater without adverse environmental or health effects. Furthermore, treated municipal wastewater reuse in agriculture represents, not just a resource to meet the growing water demand, but also a cheap source of nutrients (nitrogen and phosphorus).
The economy of Apulia region (Southern Italy) is based on agriculture despite its strong lack of water availability. Here, the combination of dry weather conditions, absence of permanent rivers and natural lakes, and progressive groundwater salinization due to overexploitation requires the adoption of non-conventional resources such as treated wastewater. In Italy, the agricultural use of reclaimed wastewater (municipal and agro-industrial) is regulated by Ministerial Decree no.185/2003 that impose highly restrictive threshold value in order to avoid adverse health effects.
In order to redefine the strict limits of the Italian laws and allow a more correct use of wastewater in agriculture, a three-years activity, at the municipal wastewater treatment plant of Trinitapoli (Apulia region), was performed. It was tested the microbial effects of the impact of three different sources of treated municipal wastewater (secondary-treated municipal wastewater, tertiary-filtered municipal wastewater and simplified lagooning treatment, all with different grade of contamination) compared with well water source on vegetable crops (tomato, fennel, lettuce) planted in succession in open ground. Water samples were collected at every watering, soil and vegetables at harvesting time and analyzed for chemical and microbiological parameters.
The results showed the suitability of the tested technologies for wastewater reclamation, indicated the good performance of surface filtration processes in the removal of faecal contamination indicators, and confirmed the positive role of nutrients in enhancing crop productions.

Key words: *treated wastewater, agricultural reuse, nutrients preservation, vegetable crops, faecal indicators.*

SESSION:

SOIL-PLANT-ATMOSPHERE CONTINUUM

MOVEMENT OF WATER AND NUTRIENTS IN THE SOIL-PLANT-ATMOSPHERE CONTINUUM

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Extended Abstract

The water transport in the soil–plant–atmosphere continuum (SPAC) is intimately related to carbon assimilation due to sharing of transport pathways by CO2 and water vapor, as they both pass through leaf stomata. Plants have evolved mechanisms to counterbalance their needs to restrict water loss by closing stomata on the one, and maximize carbon fixation by maintaining stomata open on the other. The development of a dense and extensive root system increases the potential of the plants to acquire water from a large soil volume. Through their vascular system, the higher plants are able to transport water to the leaves so as to compensate for water losses through transpiration. Water movement through the SPAC is governed by water dynamics in three main compartments, particularly soil, plant tissues, and atmosphere, and through the soil–root interface and the interface between leaf surface and atmosphere. The driving force for water movement from the root to the leaves is provided by the gradient in total water potential between the soil and the atmosphere. Maintaining a sufficient gradient in water potential is essential for the plants to cover the evaporative demand and maintain adequate hydration of their tissues. Water evaporates and diffuses from the mesophyll and epidermal cells to the atmosphere mainly through the stomata, but to a lesser extend also directly through the cuticle (Passioura, 1982). The leaf stomata are equipped with guard cells which, through their movements, are capable of modulating the size of stomatal aperture, thereby enabling plants to regulate water losses through transpiration. The regulatory mechanism of stomata opening enables plants to maintain equilibrium between the rates of water transport from the root to the leaves and the rates of transpiration. Nevertheless, from an agronomical point of view, sufficiently high rates of water transport to the leaves should be maintained, so as to achieve equilibrium at the maximum of stomata opening, thereby maximizing CO2 transport rates from the atmosphere to the mesophyl and thus net photosynthesis. Thus, timely crop irrigation at rates maintaining availability of water in the soil to optimal levels is crucial for maximizing plant biomass production through photosynthesis. On the other hand, a low vapor pressure deficit in the atmosphere reduces the water potential gradient between the nearly saturated stomatal cavity and the external air. As a result, relatively low transpiration rates are maintained that can equilibrate the rates of water transport from the root to the leaves without any need for stomata closure.

Thus, environmental conditions and cultural practices contributing to maintenance of relatively low VPD in the atmosphere also maximize photosynthesis and thus crop performance. Nevertheless, the upward transport of water from the root to the leaves through the xylem vessels contributes also to the transport of nutrients. Hence, maintaining transpiration rates to a certain level is essential for sufficient transport of nutrients from the soil to the shoot, especially those that are not mobile through the symplast.

Keywords: *soil–plant–atmosphere continuum, stomatal conductance, transpiration, water relations, xylem vessels*

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RAPESEED (BRASSICA NAPUS L.) IRRIGATION SCHEDULING VIA CROP WATER STRESS INDEX (CWSI) USING LINE SOURCE SPRINKLER IRRIGATION

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Abstract

This study was aimed to research the effects of supplemental irrigation applications on yield response to water and the usage possibilities of crop base irrigation scheduling techniques on rapeseed (Brassica napus L.) cultivation.
In the research, line source sprinkler irrigation system was used. In this layout, irrigation system treatment included both different irrigation water level and crop development period. Thus, distribution of water was uniform throughout the lateral line, and with distance from the lateral line to linear decrease for water distribution level occurred. The experiment's irrigation applications were set up as: full irrigation (III, irrigation at each three growth period), irrigation at crop vegetative period (I00), flowering period, and early ripening period in addition to non-irrigated treatment. At the same time, in consequence of using line source sprinkler irrigation method, five different water levels occurred from I1 to I5 for each treatment.
The ET and rapeseed yield values were reached from III-I1 treatment as the maximum value in each experiment year. The values of ET and yield were obtained as 730 mm and 477 kg da-1, respectively, in 2011. At the same year, the measurements of IRT were also performed.
The crop water stress index (CWSI) was calculated from measurements of infrared (IRT) canopy temperatures, ambient air temperatures and vapor pressure deficit (VPD) values for all irrigation levels. Lower limit baseline equation was calculated from the determination of the linear regression of the Tc-Ta and VPD values by the measurement of IRT's on the treatment of full irrigation (III) water level (I1), which was no water stress condition. However, upper limit baseline was calculated by using the measurement of the non-irrigated treatment (000). Upper limit changed in the graph as nearby 2.0°C for rapeseed cultivation in region. The lower limit baseline equation was obtained as Tc - Ta = -3,1375 VPD + 1,8434 from the treatment of III-I1. 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 CWSI of about 0.21 before irrigation produced the maximum yield. In addition, the linear equation of Y = -1762,5 CWSI + 717,6 was found to be used between yield and CWSI values for the prediction of yield. Eventually, it can be expressed that the CWSI values could be used in the estimation of rapeseed yield and the irrigation scheduling.

Keywords: *baseline equations, canopy temperature, crop yield, supplemental irrigation.*

THE ROLE OF INTRA-SPECIFIC BIODIVERSITY TO COPE WITH CLIMATE CHANGE: A CASE STUDY ON DURUM WHEAT CULTIVARS

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Abstract

The perspective of climate change requires an analysis of adaptation options for species currently cultivated. The relevant intra-specific biodiversity of crops may be a powerful tool for adaptation. Therefore the knowledge, for different crop cultivars, of the responses to different environmental conditions (e.g. cultivar-specific yield response functions to water regime) can allow identifying adaptation options to future climate and responsivity to supplemental irrigation. Models of crop response to environmental forcing might be used for this purpose, but their use is severely constrained by the very scarce knowledge on cultivar-specific values of model parameters, thus limiting the potential exploitation of intra-specific biodiversity towards adaptation.
We have developed an approach to identify adaptation options that relies on three complementary elements:

- a database on climatic requirements of durum wheat cultivars: the yield response functions to water availability were determined both from scientific literature and field experiments. Cultivar-specific climatic requirements were thus determined with respect to soil water availability;
- simulations performed with the agro-hydrological model SWAP to determine the soil water regime, accounting for soils hydrological properties and climate forcing. The hydrological indicator Relative EvapoTranspiration Deficit was calculated for a reference and a future climate case and for each soil type within the study area;
- comparison of hydrological indicators with cultivar-specific requirements for all combinations of climate, cultivar and soil types to identify options for adaptation.

The selected study area is a hilly region of about 40,000 ha in Southern Italy (Fortore Beneventano, Campania Region). In this area three soils types were identified and deemed representative of the whole area. Two climate cases were studied: “reference” (1961-1990) and “future” (2021-2050), produced within the Italian National Project AGROSCENARI. The reference climate case was generated from climatic statistics on observed variables while the future climate case was obtained 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 regular grid with a spatial resolution of 35 x 35 km. The downscaled climate case includes 50 realizations of daily data. By means of the SWAP model the soil water regime was described in the three soil types using the Relative EvapoTranspiration Deficit (RETD). Cultivars hydrologic requirements were compared with the simulated values of RETD and the comparison was performed for each soil type, cultivar and climate realization to assess adaptability.
In the future climate case, during the cropping season (December-June), a significant reduction (about 80 mm) of rainfall is foreseen, in particular during Spring. According to the soils hydrological indicators values and to the cultivar-specific requirements, the adaptability of several durum wheat cultivars (Waha, Haurani, Cham 5, Cham 1, Balcali 85, Cappelli, Creso, Simeto and Claudio) was assessed. The results indicate different adaptability among cultivars, soil types and climate cases. The different physical properties of the three soil types and the difference in the rainfall regime, occurring between the two climate cases, strongly affected the adaptability of the cultivars.
The case study shows how, in the future climate scenario, the intra-specific biodiversity would allow maintaining current crop production system. Moreover, in the future climate, the reduction of precipitation could require supplemental irrigation as another tool to cope with climate change.

Keywords: *adaptability, simulation models, hydrologic requirements, soil water availability*

ROOT SIGNALING AND TREE PHYSIOLOGY IN RELATION TO IRRIGATION METHODS

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Abstract

Irrigation methods differ in the amount of soil surface and wetting volume. Soil moisture is among the most dominant variable affecting plant water relations, however there are still some physiological issues not fully explored especially for abundants of hormones at root scale. Soil moisture is also involved in the CO2 soil emission processes, however information on the impact of various irrigation systems on these emissions are limited. Therefore this study compared the influence of micro-jet (MJ) and drip irrigation methods (D) on levels of ABA and indole acetic acid (IAA) in roots and on soil CO2 emission.Two plots were identified at a peach orchard (1666 p ha-1) located in Southern Italy, and irrigated by MJ (35 L h-1) and D (16 L h-1). Irrigation volumes were calculated according to ET0 released by local weather station. Plant water status (pre-dawn leaf water potential) was kept optimal in both plots. In mid summer, roots were sampled along the row and inter-row position for ABA and IAA determinations (ELISA), similarly CO2 soil emissions were measured. Results reveal that ABA is increased in inter-row roots at the D plot being 1.84-fold higher than those of MJ, despite both plots had similar water status. The CO2 soil emissions were substantially 31.8% lower in D plot compared to the MJ one. Based on the physiological effect of ABA and carbon gain and the overall low CO2 soil emissions observed in D plot, the ecological significance of the irrigation method is discussed.

Keywords: *water use efficiency, hormonal interaction, abscisic acid, indole-acetic acid, drought stress*

IMPACT OF CLIMATE CHANGE ON WATER REQUIREMENTS AND YIELD OF MAIZE GROWN UNDER DIFFERENT PEDO-CLIMATIC CONDITIONS IN BOSNIA AND HERZEGOVINA

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Abstract

Bosnia and Herzegovina is located in a specific transitional area between Mediterranean and continental climate where the impact of climate change could be particularly relevant. The phenomenon of extreme events is manifested by the absence of precipitation for several months and higher than average temperatures with several weeks which resulted in droughts (2007, 2011, 2012 and 2015). On the other hand, the high intensity rainfalls caused spills and flooding, increased groundwater level of already shallow aquifers, soil erosion and landslides, as well as a drastic reduction of agricultural production (in 2009, 2010 and in May of 2014). Climate change affected especially the growth and yield of summer field crops, traditionally grown under rainfed condition. Hence, the aim of this study was to investigate the impact of climate change on water requirements and yield of maize grown under different pedo-climatic conditions of Bosnia and Herzegovina. More specifically, the study focused on several areas characterized as main maize production zones, with the aim to determine what is the expected maize yield in the future, and to what extent it depends on the soil type and amount of precipitation.
The analysis was done by using AquaCrop growth model and the outputs of relevant regional climate model EBU-POM (Eta Belgrade University - Princeton Ocean Model) for climate scenarios A1B, A2 and A1B> CO2, A2> CO2 for the 20's (2010-2039); 50's (2040-2069) and 80's (2070-2099). The impact of climate change on maize yields and water requirements was studied for three spatially distant locations (Banja Luka on north-west, Bijeljina on north-east and Mostar on south), with their specific pedo-climatic characteristics and the expected variation of climate variables in the future. A reference level for comparison was period 1961-1990.
Calibration data were obtained from various experimental trials carried out in the target areas for different fertility, plant density and sowing period. A special attention was paid to find reliable climatic conditions to determine sowing period since it could be particularly affected by the climate change in the future. The validation of EBU-POM model was done for the reference period 1961 -1990. It was assumed that irrigation would applied when 80% of readily available water was depleted and the soil was replenished up to -30 mm of the field capacity. Difference in obtained yield

using measured and predictied climatic data varied from 0.5 up to 10.7%. Irrigation amounts for the reference period were 106, 166 and 182 mm for Banja Luka, Bijeljina and Mostar, respectively. Similar irrigation amounts were obtained using the modeled climatic data with a a difference of 1, 10 and 13 mm, respectively.
In the future climatic scenarios, the yield of rainfed maize was either reduced or slightly increased in some periods observing all regions. Increment occurred on the location where drainage problem existed during 1961-1990, such as Banja Luka and Mostar. In the period of 20's, yield reduction was expected for about 32% for Bijeljina, only up to 6% for Mostar and without reduction for Banja Luka in all scenarios. In 50's and 80's, yield reduction for Bijeljina was more severe (up to 54%) while for Mostar it was up to 14%. Irrigation would almost doubled yield in 20's in all scenarios for Bijeljina region and increase it more than 200% in 50's and 80's. For Mostar region the highest increment of yield could be expected in 20's and 50's (up to 80%) and lower in 80's (up to 46%). In Banja Luka region, irrigation would increase yield from 17 to 33% and the highest increment would be obtained in 80' in A2 scenario. Irrigation needs are expected to increase for Bijeljina up to 231 mm in 20's, 270 mm in 50's and 273 mm in 80's. The higher values are expected in A1B and A2 and lower ones in scenarios with elevated CO2. For Mostar region, irrigation amount was increased up to 240 mm in A1B scenarios and 230 mm in A2 scenarios for the whole period. In Banja Luka region, irrigation need was increased from 13 - 35 mm in 20's up to 100 mm in 80's. Therefore, the adoption of irrigation is urgent adaptation measure in order to ensure stable and high yield of strategic crops such as maize.

Keywords: *rainfed cultivation, irrigation, aquacrop, sowing period.*

THE IMPORTANCE OF WATER CONSUMPTION IN AGRICULTURE UNDER THE EFFECT OF CHANGING OF CLIMATE AND GLOBAL HEATING

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Abstract

Inefficient use and increasing scarcity of water resources, drought, loss of biodiversity, plant cover and soil erosion, environment pollution, changing of climate and global heating, decrease of ozone layer, increased greenhouse gas emission, occurred since the beginning of global heating period.These events affect socio-economic sectors and also ecological balance, both directly and indirectly. This situation creates many important problems.
Uncontrolled irrigation and low efficiency methods are used as approximately 90% of agricultural water use in Türkiye. The problem of salinity and aridity occured on the soil of some regions due to irrigation in the Southeast Anatolia Project (GAP) area. For this reason, logical water management applications and sustainable agriculture must be used for protection of soil and preservation of agricultural areas for next generations. For this aim, using of waste water for irrigation, water harvesting, modern irrigation methods, and efforts for farmers education should be supported.
In this study, the options for sensible use of soil and water under the effect of climatic changing in Türkiye were discussed, with focus on sustainable water management.

Keywords: *climatic conditions, drought, modern irrigation systems, water management.*

IMPLEMENTATION OF A REGIONAL PARAMETRIC MODEL FOR POTENTIAL EVAPOTRANSPIRATION ASSESSMENT

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Abstract

Potential evapotranspiration (PET) is key input in water resources, agricultural and environmental modelling. For many decades, several approaches have been proposed for the consistent estimation of PET at several time scales of interest. The most recognized is the Penman-Monteith formula, which is yet difficult to apply, since it requires simultaneous measurements of four meteorological variables (temperature, sunshine duration, humidity, wind velocity). For this reason, simplified approaches prove very useful in absence of a complete data set and are strongly preferred. In the present study, we implement a recent parametric formula to model PET in the Arta plain, located in the Region of Epirus - Greece, which is based on a simplified formulation of the original Penman-Monteith expression and requires only mean hourly, daily or monthly temperature data, depending on the desired time step. The methodology is generic, yet parsimonious in terms of the input data, with its parameters adjusted through calibration, to the available PET data. A spatial analysis concerning the regionalization of the parameters and the comparison of PET estimates between the Penman-Monteith formula and the proposed methodology by implementing interpolation techniques is performed. The results are very satisfactory, illustrating that the proposed framework is efficient and constitutes a reliable alternative in the assessment of potential evapotranspiration field.

Keywords: *evapotranspiration, Penman-Monteith method, modelling, calibration, spatial analysis*

EFFECTS OF SUBSTRATE WATER CONTENT ON TWO MEDITERRANEAN ORNAMENTAL SHRUBS

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Abstract

Water deficit is considered the main limiting factor for plant growth in the Mediterranean region during summer because of the high evapotranspiration demand. Water shortage could limit plant management for landscape activity. The study of plant response to water stress and morpho-physiological mechanisms related to drought tolerance may be useful for improving landscape management in Mediterranean area.
The experimental trial was carried out in an unheated greenhouse that was located in Catania, Italy. Two ornamental shrubs (Polygala myrtifolia L. and Viburnum tinus L. 'Lucidum'), were transplanted into 3.3-L pots. The irrigation was controlled by an automated irrigation system through the use of dielectric sensors EC 5TE of Decagon Device in order to maintain four volumetric water contents in the substrate: 40%, 30%, 20% and 10%. In the used substrate, the highest value correspond to a tension of -5 kPa. The experiment was conducted as a randomized complete block design with three replicates (the species were randomized within blocks); each experimental unit consisted of twenty plants. The trial started on 15 July 2014 and lasted 100 days. At the end of the experiment nine pots per treatment (three per replication) were randomly chosen for the measurement of the following parameters: dry weight production and partitioning, leaf number, leaf characteristics. Monthly, during the experimental period, the gas exchanges, the chlorophyll a fluorescence, the pre-dawn and midday leaf water potential and relative water content were measured on fully opened leaves. At the end of the experiment, the water regimes altered several morphological and physiological parameters. The water stress reduced epigeous dry weight by 48% in Polygala and 41% in Viburnum from control to more stressed plants; mainly because of the reduction of leaf dry weight. Only in Polygala the drought stress modified the root/shoot ratio. Treatments decreased the number of leaves, the total leaf area and the unit leaf area especially in Polygala. At the end of the experiment leaf water potential pre-dawn was reduced in both species in correspondence of the more stressed treatment (10%), showing values of -1.5 MPa in Polygala and -0.90 MPa in Viburnum. The net photosynthesis rate linearly decreased in both species in relation to water stress, particularly in Polygala. This reduction was mainly linked to stomatal conductance variation, as shown by the significant correlation between the two parameters. The quantum yield of PSII in

stressed plants was reduced only in Polygala, to confirm the susceptibility to drought stress of this species.

Keywords: *water deficit, drought stress, water potential, polygala myrtifolia l., viburnum tinus l. 'lucidum'*

USE OF CAPACITANCE SOIL MOISTURE SENSORS FOR ASSESSING THE EFFECTS OF DIFFERENT SUBSTRATE WATER CONTENT ON GROWTH AND WATER RELATIONS OF SOILLESS TOMATO

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Abstract

The increasing availability of low-cost and reliable substrate moisture sensors offers interesting perspectives for rational and automatic irrigation management of soilless greenhouse crops and for research on plant water relations. The knowledge of the effects of different substrate volumetric water content (VWC) levels on plant growth is crucial for the determination of proper irrigation set-points. An experiment was conducted to assess the effects of different VWC levels on soilless tomato growth and water relations. Tomato plants were grown in a greenhouse in perlite bags. An automatic irrigation system used substrate moisture sensors to control irrigation solenoid valves, in order to keep growing media at four different VWC levels (0.15, 0.20, 0.25 and 0.30 $m^3 \cdot m^{-3}$). The system was able to get the substrate VWC at the desired different set-points. Substrate water potential was monitored during the experiment using tensiometers. The four VWC levels resulted, respectively, in a mean substrate water potential of -130, -101, -42 and -34 hPa. Plant growth was similar for plants grown at 0.30 and 0.25 $m^3 \cdot m^{-3}$ in terms of leaf area, fresh and dry weight, with higher values than plants grown at 0.20 and 0.15 m3·m-3. Plant water status was affected by the VWC level in the substrate, with higher and similar values of total leaf water potential for plants grown at the two highest VWC levels than those grown at lower VWC. The most severe effects of water stress were observed on plants grown at 0.15 $m^3 \cdot m^{-3}$ which showed the lowest leaf relative water content (respectively 64.4% vs 84.8% at higher VWC levels) and membrane stability index (respectively 68.6% vs 83.9% at higher VWC levels). The water retention curve and hydraulic conductivity analysis performed on the perlite substrate used in this experiment revealed little or no available water below a VWC of about 0.15 $m^3 \cdot m^{-3}$. However, plants grown at 0.15 $m^3 \cdot m^{-3}$, were able to uptake water from the growing media and thus to survive, although showing reduced growth and symptoms of water stress. Results seem to confirm that soilless growing media generally hold easily available water in a matric potential range from 0 to -100 hPa, with the majority of free available water present between matric potentials of 0 to -50 hPa.

Keywords: *perlite, EC5 probe, solanum lycopersicum, water potential*

This work has been supported by project "Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes" (IRMA) - European Territorial Cooperation Programmes (ETCP), GREECE-ITALY 2007-2013.

SESSION:

INNOVATIVE TOOLS FOR IRRIGATION MANAGEMENT AT FARM AND DISTRICT LEVEL

MODERN APPROACHES AND TOOLS FOR IRRIGATION MANAGEMENT: FROM RESEARCH ACHIEVEMENTS TO ON-FIELD APPLICATIONS

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Extended abstract

Management of water resources in agriculture is evolving from a pure technical issue to a modern and transparent decision-making process which involved different horizontal and vertical levels of stakeholders and decision makers. This happens due to i) rising needs to adopt new water management strategies and approaches suited to face on-going climate change and environmental burden, and ii) incessant, almost daily, advancement of monitoring devices (direct and remote) and information and communication technologies (ICT). On one side, water management strategies have been revised introducing for different scales new terms as water productivity (at plant, canopy and farm level), eco-efficiency (at farm, district and national level) and water footprint and virtual water (at national scale), and new concepts as water-energy-food nexus . On the other, new generation of relatively low cost technologies was developed for monitoring of i) soil-plant-atmosphere continuum in the fields, ii) water availability in dams, aquifers and rivers, and iii) water conveyance and on-farm application. These technologies promote both direct and remote control of irrigation and offer the adoption of various airborne options (e.g. from drones to new generation satellites). Nowadays, the new management strategies and technological achievements converge towards complex, integrated, multi-scale solutions able to satisfy different types of users, from a single farmer to large irrigation districts. Accordingly, to support the implementation of these solutions on the ground, the European Union has launched several initiatives and funds as they are the European Innovation Partnership on Water (EIP Water), European Agricultural Fund for Rural Development (EAFRD), H2020 and other programs. However, it is still complicated to transfer effectively the latest achievements to the fields due to i) complexity, heterogeneity, fragility and non-stationarity of soil-plant-atmosphere continuum and pertinent water systems and ii) continuous update and frequent incompatibility of ICT. This study presents some of the examples of practical application and advancement of modern technologies at different scales in the Mediterranean environments.

Hydro-Tech decision support tool was developed in 2012-2014 by a consortium of private ITC companies and research institutions within the framework of the EAFRD program managed by Apulia region. Hydro-Tech integrated agronomic and engineering aspects of water management and can be applied at both farm and irrigation district scale combining the advanced technological solutions for the

continuous sensor-based monitoring of the soil-plant-atmosphere continuum and the remote control of irrigation supply networks. Soil water balance model is the core component of the system and runs on a daily basis. It is based on the standard FAO-56 approach for the estimation of reference evapotranspiration (ETo) using the Penman-Monteith equation and determination of crop water requirements and irrigation inputs under different water management strategies (Allen et al., 1998). The system has a modular and flexible structure which permits its adaptation to the user specific scenarios based on the real on-farm conditions and constraints. Hence, additional tools were settled for the estimation of ETo under limited data availability and development of the crop coefficient curves according to the adopted on-field management practices and crop specific biometric and phenological characteristics. The crop development is modelled by means of both calendar-day and heat-unit concepts. Simulation includes the high-resolution weather forecasting data which permits the pro-active irrigation management considering 3 to 7 forthcoming days. A dynamic multi-crop/farm optimizer supports the user-defined setting of constraints and irrigation priorities at the farm scale by taking into account the water availability at its quality, the soil water moisture level and eventual crop water stress. Hydro-Tech provides standard interfaces connecting the on-field devices with the client software application through a Data Cloud Network (Hydrotech Data Cloud, HDC) which permits wireless, via new generation of smart devices (tablets, smartphones), and continuous monitoring of the on-field conditions and the remote control and management of irrigation. In remote areas, in the absence of GSM/GPRS coverage, the systems employs a new generation of the wireless radio-band transmission of data from/to hydrants, pumps and other sensors. Hydro-Tech is actually operated in the Apulia Region (Italy) at different farms for the irrigation management of peach and olive orchards, wine and table grapes, and vegetables. The system is now evolving into a commercial brand of Blueleaf (www.blueleaf.it). On-going enhancement focusses on the introduction of a module for the use of low-quality water in agriculture and the adoption of eco-efficiency approach which will permit full consideration of environmental and economic aspects of irrigation management. In the recent years, the concept of eco-efficiency has been introduced as a tool to analyze the sustainability of management practices and agricultural production at different scales, from farm to district. Todorovic et al. (2015) presented a new methodological approach for the eco-efficiency assessment of meso-level agricultural water systems and its application to Sinistra Ofanto irrigation scheme (Southern Italy). The methodology was developed in the frame of the EcoWater project (EC-FP7-ENV) and aimed at the uptake of new technological solutions for the improvement of eco-efficiency throughout the water pathway from the source to the fields. The environmental performance was addressed by life-cycle-assessment using mid-point indicators, while the economic performance was measured using the total value added due to water use and adopted management practices. The assessment identified the environmental impacts of specific stages/processes across the entire value chain and supported the stakeholders to improve the water system management and eco-efficiency performance. The eco-efficiency assessment was performed using new modelling tools (EcoWater, 2014): the Systemic Environmental Analysis Tool (SEAT) and the Economic Value Analysis Tool (EVAT). SEAT permits the simulation of the water use system, along with its components, processes and

interactions, as well as the evaluation and visualization of material and energy flows and categorizes them into impact categories. The model described the elementary flows of resources and emissions that are necessary for evaluating the environmental impacts. Moreover, SEAT depicted the flows of water, products and other materials that permit the estimation of the costs and incomes generated by the system and quantify the interactions among the actors. Then, the results of SEAT are used in EVAT to perform the economic assessment across the analyzed value chain. EVAT elaborated the added value to the final product due to water use from stage to stage and the allocation of costs and incomes among the chain stages and actors. The presented methodology can be used to compare the performance of the system from one year to the next, among different stakeholders (water users) and/or to assess the impact of adopting innovative technologies and management practices. Likewise, this approach is useful for comparing the performance among different agricultural water systems and also in respect to other meso-level water systems in a cross-sectorial analysis.

The overall experiences from the recent activities on the implementation of innovative approaches and management tools confirmed that:

- Technologies are mature to be effectively applied for irrigation management at different scales;
- Potential users (from farmers to large scale district managers and decision makers) have real need to apply new technological solutions on the ground which permits transparent management and governance of the resources in agreement with modern standards and approaches;
- Innovative solutions should be tailored to specific pedo-climatic conditions and socio-economic, environmental, cultural and political scenarios;
- On-ground implementation of innovations requires reliance and continuous dialogue and exchange of ideas between technology providers, potential users and funding agencies;
- New technological solutions require the integration of monitoring systems and management tools (agronomic, engineering, environmental and economic) at different scales and decision levels and full involvement of all pertinent stakeholders.

Keywords: *eco-efficiency, irrigation management, decision support system, resources use efficiency, wireless communication, automated control.*

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SATELLITE VS. GROUND-BASED MONITORING OF DURUM WHEAT BIOMETRIC AND PHYSIOLOGICAL PARAMETERS

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Abstract

Nowadays, the remote sensing technologies have been widely studied by many research programs. An evaluation and standardization of the available sensors is becoming a necessity after the increase of the sensors number and way of data acquisition for agricultural purposes. The aim of this study was to compare two remote sensing techniques (satellite and ground-based) as tools describing the variations of physiological and biometric parameters of durum wheat grown under different water regimes. The experimental layout was established in Policoro (Matera) located in Southern Italy about 3 km far from the Ionian coast. The growing season was from February to June with three distinguished water management practices (rainfed, 50% and 100% of irrigation requirements). The Landsat 8 images and radiometric ground-based data were acquired regularly in April, May and June together with plant biometric and physiological parameters. The overall results indicated no significant difference of biomass and yield for different irrigation regimes. This could be explained by large precipitation amount (205 mm) regularly distributed during the season which limited the needs for irrigation (105 and 52.5 mm for 100% and 50% irrigation, respectively). Soil adjusted vegetation index (SAVI) showed slightly better performance than normalized difference vegetation index (NDVI) when plotted against the leaf area index (LAI). The regression coefficient of such relationship was greater if based on the ground than on the satellite data. Therefore, it could be concluded that in site vegetation indices describe the LAI with higher fidelity than those from the satellite system. Nevertheless, the satellite data could provide reasonable indications about the crop growth when other means of measurement are missing.

Keywords: *NDVI, SAVI, vegetative indices, LAI, stomatal conductance.*

MANAGEMENT OF HYBRID IRRIGATION METHOD FOR ENHANCING CROP WATER PRODUCTIVITY IN OLD LAND IN EGYPT

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Abstract

The WLI project of Egypt aims to improve livelihoods of households and communities in the Nile Delta, which represents the major agricultural region in Egypt (about 70% of the agricultural area). WLI-Egypt activities are primarily focusing on three benchmark sites located in old lands, salt-affected lands, and new lands. This study focused on the old land site, which represents clay soils in the Nile Valley and Delta. The project is seeking to improve the rural livelihood concerning with sustainable management of land and water. In the winter season of 2013/2014 and the summer season of 2014, two trials were conducted in clay soil at Zankalon Experiment Station in the east Nile Delta of Egypt to investigate the performance of the multi-outlet hybrid irrigation for irrigating Egyptian clover (berseem) and Cotton, respectively, compared with lined ditches irrigation system. The finding of the research evidently indicated that the multi-outlet hybrid irrigation system saved irrigation water by 10.3 and 9.15 % for Egyptian clover (berseem) and Cotton compared with lined ditches irrigation system, respectively. The fresh berseem yield was decreased by 2.8 %, however, crop water productivity was increased by 3.1 %, because less water was applied than with lined ditches which have lower water application efficiency compared with the multi-outlet hybrid irrigation system. On the other hand, the multi-outlet hybrid irrigation system recorded a significant and slight increase in the yield and crop water productivity of cotton crop, respectively. Ultimately, the multi-outlet hybrid irrigation system saves water, increases dry yields, improves crop water productivity of studied crops, but fresh yield with lined ditches are higher due to the excessive water applications that they receive compared with the multi-outlet irrigation system.

Keywords: *multi-outlet hybrid irrigation system, distribution and application efficiencies, feasibility study, advance time, livelihoods.*

LONG-FURROW IRRIGATION SYSTEM PERFORMANCE UNDER CONDITIONS OF NORTH AND SOUTH SINAI -EGYPT

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Abstract

This study analyzes the relationship between the variables of long-furrow irrigation system and the irrigation performance parameters, and crop yield, at marginal environments as a basis for furrow irrigation design and management. Field studies were conducted over two consecutive summer seasons (2012 and 2013), in RasSudr Experimental Station of the Desert Research Center, irrigated by ground water source (will be denoted as “field 1”) via 100 m field length, and El-Tina Plain at North Sinai, irrigated with surface water source (will be denoted as “field 2”) via 160 m field length, the long furrows cultivated by sorghum crop. Irrigation water was applied through PVC spill pipes (each unit 1.0 m length and 63 mm diameter plus movable end cap) as flexible technology and cheap tool for irrigation water distribution control at on-farm level, with good control of discharge rate and duration time under the user scheme (farmer) by moving the end caps, which it installed to passing water to the upper inlet of irrigation furrows according to the required equality of water discharge into furrows (one spill pipe each furrow).

The experiments were carried out in a split-split plot design with three replicates. In each site, the main plots represented two longitudinal soil surface slopes: 0.1 and 0.16%, namely: S1, and S2, respectively. The sub plots represented two water inflow rates: 84 and 108 lpm/furrow in field 1 designated as Q1, and Q2, respectively. Q3, and Q4 were 135 and 168 lpm/furrow in field 2. The irrigation performance was evaluated through four parameters: application efficiency (AE), requirement efficiency (RE), requirement distribution efficiency (RDE), total distribution efficiency (TDE) compared with traditional short furrows. Also, furrow irrigation management, operation, and design variables (inflow discharge, furrow length, and irrigation cut off time) were correlated. The relationship between performance irrigation parameters and relative crop yield was also examined and estimated as irrigation water use efficiency (IWUE) for different treatments.

The obtained results indicated that the total distribution efficiency is the performance irrigation parameter that can express conditions of either deficit or over-application of water in furrow irrigation. Thus, TDE and AE are recommended to be used for the design, management, and operation of furrow irrigation system, to establish good irrigation practices.

Keywords: *marginal environments, long-furrows, spill pipes, irrigation performance, sorghum yield*

LOW PRESSURE SUBSURFACE IRRIGATION TECHNIQUE FOR A PRECISION AND OPTIMAL IRRIGATION MANAGEMENT

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Abstract

This paper presents analysis and results of a joint research project between the Technical and Scien¬tific Research Center on Arid Regions (CRSTRA) in Biskra (Algeria) and the Department for Agricul¬tural Engineering of the Kassel University (Germany). An auto-regulative permeable pipe buried beneath the soil surface was tested in greenhouse trials at the experimental station El Outaya near Biskra (Algeria) under semiarid to arid conditions. The new irrigation system works at low pressure to allow an auto-regulative functioning of the pipe, based on porous irrigation pipes as an upgrade of both subsurface and traditional pot irrigation. In clay pot (pitcher) irrigation unglazed porous clay pots are embedded in the ground and filled with water, which eventually drains through the porous pot wall. Savings of up to 70 % compared with conventional irrigation methods were observed, as well as a significant reduction of fertilizer requirements. To sustain a constant low system head a mechanical float valve is upstream of the irrigation pipes ensuring continuous water filling of the pipe. The irrigation method works automatically and independent of energy supply. To compare the new irrigation system with the drip irrigation technique two greenhouses were equipped with drip irrigation and the permeable pipes respectively. The greenhouses were divided into different plots and planted with tomatoes. Two types of irrigation water were tested; surface water from a local dam and groundwater with a higher salinity. Results show 60 % higher yield for the permeable pipe irrigation with 48 % less water consumed compared to drip irrigation when using poor quality / salty irrigation water. The water had no measurable impact on the soil structure, and the tomato plants showed better health and performance (plant height, fruit diameter and weight) compared to the drip plots.

Keywords: *subsurface irrigation, auto-regulative, water saving, optimal management, efficient irrigation*

IRRIGA SYSTEM: IRRIGATION MANAGEMENT SERVICE

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Abstract

Irrigation remains the main reason of water consumption in the European scale, in spite of the increment in its use by other sectors than agriculture. Irrigators have been urged by the civil society to improve their efficiency to prevent water scarcity and preserve water quality. Sustainable use of water is clearly important to the society. Irriga System fills the existing gap by providing growers with a precise tool to control their irrigation. It preserves water use by recommending just the amount of water needed for the growing crop, adjusted by soil physical characteristics, irrigation method, soil physical measurements, weather data and meteorological forecast. Irriga system has a strong scientific and technological base for irrigation management and monitoring, and it is extremely practical, functional, efficient and easy to operate. It recommends the correct daily irrigation depth of water to be applied, and has the ability to schedule irrigations for the next 7 days. The system adequately fits the crop irrigation management to meet climatic demand and availability of soil water to plants, taking into consideration the influence of all factors of water balance, especially crop water demand. Detailed information about soil physical parameters, crop parameters, irrigation equipment, climatic parameters and computing procedures that Irriga System uses to precisely recommend the correct irrigation depth is available in our web page (www.irrigasystem.com). Irriga System provides a service of irrigation management indicating how much water depth has to be applied on each growing field during the entire growing season. The mathematical models used by the system simulate and quantify the soil profile water balance, crop growth and development, reference evapotranspiration, among other factors. Throughout the crop growing season our technical field staff makes periodic visits to all growers and fields (every 10-14 days). Field technicians closely follow the grower during the entire irrigation period. They are well trained and possess adequate knowledge of all the processes involving the use of recommendations, from data collection, survey and analysis of all operating requirements, planning and distribution of irrigation. During the field visits, the technicians determine: soil moisture of the soil profile, in locations representative of the irrigated area, the mean phenological stage of the crop, the depth of the plant root system, plant height, leaf area index and plant population, in addition to observing the phyto-sanitary aspects of the crops. The irrigation recommendations are available to growers 24 hours a day,

seven days a week, through the Irriga System's website. During the year of 2014 the irrigation management service was provided for more than140,000 hectares. Main advantages in using Irriga system are: (i) increases crop and water productivity; (ii) saves water and energy; (iii) significantly contributes to environmental balance and sustainability; (iv) reduce the risk of production losses due to water stress or excess; (v) very practical to operate and require minimal interference of the grower in the configuration or operation of the system and; (vi) recommendations are obtained at real-time via Internet access, smartphones, SMS or phone calls.

Keywords: *irrigation management, water balance, crop evapotranspiration, soil moisture*

INNOVATION AND THE WATER FOOTPRINT (WF) INDICATOR FOR ENSURING SUSTAINABLE IRRIGATION: AN EXAMPLE FROM ITALY

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Abstract

Today, Irrigation Advisory Services (IAS) based on satellite imagery are valid tools for supporting irrigation management at different spatial scales. These services are able to produce a huge amount of multitemporal data for a wide variety of irrigated crops for several irrigation districts that could be potentially used for computing water use indicators such as the water footprint (WF). This study aims to assess the variability of WF of maize cultivated in the main irrigation districts of Campania region (Southern Italy) by using a multitemporal IAS dataset and to compare their performances in terms of environmental and economic sustainability. To this aim, maize WF was estimated by using data provided by the Campania IAS for different years. The results clearly show that the use of innovative tools in irrigation management combined with the estimation of the WF indicator can contribute to assess the sustainability of water management in agriculture, especially for areas affected by water scarcity.

Keywords: *irrigation advisory services[1], sustainability[2], maize[3]*

EVALUATION OF IRRIGATION AUDITING AT A WATER DEFICIT AREA OF THESSALY –GREECE, LAKE KARLA AREA

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Abstract

The area of Karla Lake is environmentally sensitive. The last decades it has faced extensive flooding due to the region's topography, the lake's drainage, the land subsidence as a result of the groundwater overexploitation, until its reconstitute according to the RAMSAR convention. The new lake-tank works and the reconstruction of Karla Lake gave new perspective on farms, increasing the cost of irrigation water. In this article, based on the framework of Directive 2000/60 the construction and operation costs of the ponds and the cost of operation of the competent LLRA (Local Land Reclamation Agency) are analyzed, evaluating the overall financial cost of irrigation water that reaches the 0.08 €/m3 . The ever-rising cost of irrigation water in conjunction with the reduction of crop yields in the region, requires rational water management with new and more efficient methods, such as the individual and collective inspection of irrigation systems.

Keywords: *irrigation, auditing, cost, thessaly, karla*

IRRIGATION OF PYRUS IN THE VICINITY OF HISAREYN-GÖLCÜK/KOCAELI,TÜRKIYE

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Abstract

Fruit growing represents an important sector of the agricultural industry. Pyrus is a valuable fruit species, and its cultivation contributes significantly to economy in Türkiye. Pyrus trees need irrigation in the period of growing/cultivation. Irrigation is a key-factor for pyrus cultivation. Generally, application of irrigation is recommended from the beginning of May to the end of September. Irrigation methods change according to orchard's soil characteristic and climatic conditions of the cultivation area.

In this study, irrigation methods and water resources were investigated in pyrus orchards in the vicinity of Hisareyn-Gölcük/Kocaeli in Türkiye. Irrigated and un-irrigated pyrus orchards were compared. Double ring infiltrometer test has been done for the determination of soil infiltration rate and the rate has been calculated as 20.00 mm h-1. According to physical observations and determination of soil characteristics, drip irrigation was assessed to be the most suitable in the area for pyrus orchard irrigation.

Keywords: *infiltrometer, infiltration, irrigation methods, orchards, productivity, pyrus*

IRMA_SYS: A WEB-BASED IRRIGATION MANAGEMENT TOOL FOR AGRICULTURAL CULTIVATIONS AND URBAN

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Abstract

According to EU Water Framework Directive 2000/60/EC, action is needed to protect waters in both qualitative and quantitative terms. In this context a challenge of water-related issues for Mediterranean countries is to integrate water demand management in agriculture and to develop added value tools to optimize efficiency in irrigation. Potential for a -40% to -60 changes in water availability for irrigation in extended Mediterranean areas of EU countries in the near future make the necessity for optimum irrigation water managements a top priority goal especially in countries like Greece where irrigation represents the major water resources consumer (70% according to FAO-AQUASTAT). This study presents the key features of IRMA_SYS (http://arta.irrigation-management.eu/), a regional, user-friendly computer / smart phone-based, open and free modular software for estimating site specific crop water requirements and irrigation scheduling. The estimation of irrigation water requirements and irrigation scheduling is based on a modification of the FAO paper 56 approach, combining hourly and daily time steps. The system takes into account both historical and forecasted agrometeorological data, along with crop and soil-water data to accomplish its tasks. Also, it is fully customizable, allowing the users to add site and crop specific information taking advantage of additional data. Feedback and evaluation procedures are already applied and expected to contribute to the improvement of the system.

Keywords: *irrigation efficiency, irrigation scheduling, open source software, agrometeorological information*

EFFICIENT AGRICULTURAL IRRIGATION MANAGEMENT: UPGRADE OF THE IRRIGATION MODULE AND TESTING OF BLULEAF DSS

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Abstract

Apulia Region Agrometeorological Service, managed by Associazione dei Consorzi di Difesa della Puglia (ASSOCODIPUGLIA) , developed services to support farmers' activities like irrigation practice. Within the framework of the Regional Operational Program (POR) Puglia 2000-06, irrigation management model was validated for tomato crop and made available to users through the web. The model and the web interface was further revised in the framework of the IRMA project, creating the English version and making the consultation more intuitive and user-friendly. The model is able to provide advice on the amounts of needed water, depending on the crop and on the weather situation, using data collected by the stations of the Agrometeorological Service Network. In the IRMA project has been moreover experienced, in some companies pilot, the decision support system for irrigation "Bluleaf". The system is able to manage irrigation adapting the models to farm specific characteristics: i.e. customizing crop or soil basing on characteristics of the farm, defining a irrigation strategy based on Phenological Deficit Irrigation, in order to improve even more efficiency and the effectiveness of treatments.

Keywords: *precision farming, irrigation, decision support system (DSS), optimization*

THE METEOROLOGICAL STATIONS NETWORK THAT HAS BEEN INSTALLED IN THE PLAIN OF ARTA

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Abstract

The Public Service, called Decentralized Administration Of Epirus-West Macedonia (in brief DAOEWM), as a Partner of IRMA Project, was obliged to provide the purchase of 20 meteorological stations (following the standards of the World Meteorological Organization), to install them in Arta plane and as well to connect them to a network. The established net consists of six (6) Wireless (5 UHF &1 GPRS) high precision meteo-stations. These stations will be referred to as "Type A". Nine (9) internet connected high precision meteo-stations that will be referred to as "Type B" and five (5) medium precision meteo-stations, called "Type C". The communication between all stations is based on a combination of wireless UHF, GPRS connectivity and TCP / IP network via wired internet. The data from all stations are transmitted to the central computer at least every 60 minutes.
The final choice of the right place of installation for each station was made having in mind the technical specifications of each type of station (A,B, or C), the relief of the area (hills, mountains, obstacles) and the reliability of the meteo-station host, in order to achieve the best functionality possible. All the data are collected and processed by the network developed by TEI of Epirus and through an appropriate software (also soon available as a smartphone app) will be able to be freely used by agriculturists or farmers, being interested in the use of irrigation in Arta plane.

Keywords: *irrigation management, arta plane, meteostation, DAOEWM, Epirus*

IMPROVEMENT OF INFILTRATION MODELLING TO ASSESS THE EFFICIENCY OF WATER USE AND IRRIGATION SCHEDULING

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Abstract

Water scarcity is nowadays a limiting factor for crop production especially under climate change conditions. A better understanding of water processes within irrigated fields is a key factor to increase water use efficiency and to improve irrigation scheduling and water applicability. The selection of the hydrological model and, above all, the soil water model describing infiltration processes within the vadoze zone, plays a crucial factor for the quality and accuracy of model simulations.
The objective of this study is to improve infiltration and soil moisture processes within the FEST-WB model for hydrological simulation. The Flash-flood Event-based Spatially distributed rainfall-runoff Transformation–Water Balance distributed hydrological model developed at Politecnico di Milano (POLIMI), implements the Curve Number method for estimating the infiltration rate. Models based on different approximation of the Richards' equation were implemented and tested, including the Ross 2003 fast solution method. Performance improvement was tested against observations acquired in the experimental site located in a maize field in the Muzza Bassa Lodigiana (MBL) consortium in northern Italy, where soil water status was monitored using TDR and Sentek probes together with continuous measurements of meteorological data for several cropping seasons. A sensitivity analysis was performed in order to assess the most important parameters governing infiltration process in different model schemes tested also with the Curve Number method for estimating the infiltration rate. A comparison of model simulations show that methods based on solution of physically based equations better describe soil moisture variation along the vertical, but simpler lumped models provide sufficient accuracy when properly calibrated. Accurate simulations of infiltration process, using the updated version of the model, will allow us to better understand the water movement within the vadoze zone, water use efficiency during previous cropping season and can provide a decision support for an improved irrigation scheduling.

Keywords: *numerical modelling, infiltration, soil moisture profile, irrigation management*

MAPPING IRRIGATED AREAS: THE CASE STUDY OF PIVOT SYSTEMS IN THE MALLEE DISTRICTS OF THE SOUTH AUSTRALIAN MURRAY-DARLING BASIN

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Abstract

In this study we explore the potential of high- spatial and temporal resolution remote sensing data to map irrigated areas. The identification of irrigated areas is a question of great importance for the managers of water resources, both to plan a rational use of water in the presence of limited availability and to monitor possible unauthorized withdrawals of water from irrigation networks. The mapping of irrigated areas can be achieved using multi-temporal classification of vegetation indices derived from atmospherically corrected data. In semi-arid climatic conditions, the development of crops is only possible with sufficient irrigation supply. We tested an approach to estimate the irrigated areas in the Mallee Districts of the South Australian Murray-Darling Basin, where large irrigation pivot are present. We use a time series of eleven satellite acquisitions from Landsat-8 (30 m pixel size) collected during the irrigation season 2014-2015, and pre-processed to atmospherically corrected surface reflectance level using ATCOR-2. For the classification of irrigated and non-irrigated areas, we adopt a semi-automatic ISODATA algorithm using as input feature a layer stack of multi-temporal NDVI data. The same procedure was repeated using the Landsat-8 CDR dataset which is a readily-available atmospherically corrected dataset, generated by the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS). The two datasets (obtained with ATCOR and CDR) were compared considering the temporal profiles of NDVI; the final irrigated map products were also compared to ground truth. Results indicate that the irrigation pivot can be clearly identified using both datasets. However, pivots seem to be better delineated using Landsat time series corrected with ATCOR-2.

Keywords: *landsat CDR, ATCOR-2, pivot systems, irrigated areas, semi-automatic classification*

FARM MECHANIZATION AND WATER SCARCITY OPTIONS UNDER CLIMATE CHANGE SCENARIOS IN EGYPT

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Abstract

Egypt is situated in the north-eastern corner of Africa between latitudes 21O and 31O North and longitudes 25O and 35 O East, covering an area of about 1 million km2, spread as follows: Nile valley and delta represent 4% of the total area; Eastern desert is about 22%; Western desert area is about 68%; and finally Sinai Peninsula area is about 6%. The share of Nile water in Egypt is 55.5 billion m3/year, representing 76.7% of the country's available water resources; desalinated seawater comprises only 0.08%. Total groundwater plus treated water is 20.65 billion m3/year (28% of available water resources), but it cannot be added to Egypt's share of water as it is a reused source. The climatic variability is expressed by arid zones in the North to hyper-arid in the South. The climatic variability coupled with the high dependency of agriculture on the irrigation water results in the complex cropping system. Some of the major cropping sequences include Rice, Wheat, Cotton, maize, sugarcane. Within these cropping systems there is further mix of other crops in both summer and winter seasons.

In the last decade, more awareness and concern for climate change, food and pollution problems are growing to be discussed. The complexity of uncertainty basic data and indications issued by scientific authorities are sometimes misleading specially for the agricultural production sector, which have to be increased by 70% within 2050. Furthermore, agriculture will need to minimize the emissions of greenhouse gases, pesticides and plant nutrients like nitrogen and phosphorous to the environment. Agriculture will also need to adapt to climate change including more extreme weather events. In principle, there are three pathways for agricultural development: conventional agriculture, organic agriculture and conservation agriculture. These pathways have different approaches for addressing the above issues. Livestock farming plays a significant role in the agricultural economy of Egypt specially for dairy production. Most of buffaloes, however, are the primary milk producing animals and are found in the irrigated areas, sheep in recent years, herds are also being raised in new reclaimed areas. With this background having complex climate, agricultural production and cropping system variability, it is highly complex to address the farm mechanization issue especially in the context of changing climate scenario.

Keywords: *climate change, water policy, irrigation techniques, Egypt*

SESSION:

MODERN STRATEGIES FOR WATER MANAGEMENT UNDER PROTECTED ENVIRONMENT

MODERN STRATEGIES FOR IRRIGATION MANAGEMENT IN PROTECTED ENVIRONMENTS

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Extended abstract

Water availability and quality are important issues throughout much of the world. Severe droughts are increasingly common and saltwater intrusion threatens to quality of the groundwater in many coastal areas, Water quality issues resulting from runoff of excess irrigation water with dissolved agrochemicals also are a major concern. These issues affect agriculture, including the greenhouse industry. One of the challenges the greenhouse industry will need to address is to decrease water use and minimize any negative environmental impact from greenhouse production.
For the last decade, we have been working on ways to help the greenhouse industry reach those goals. We have focused on the use of sensors to provide growers with the information they need to make better irrigation decisions. We have also developed hardware and software that helps growers automate irrigation based on that information. And we are working on ways to help growers make more informed nutrient management decisions. Our basic approach is simple: we use soil moisture sensors to measure how wet the substrate is. When the substrate gets too dry, the crop is automatically irrigated. This results in on-demand irrigation: when crops use a lot of water, they automatically get irrigated more frequently.
We have done trials in university greenhouses and in commercial greenhouses. Our work with commercial growers has given us many insights into the potential benefits of precision irrigation. The following sections provide a description of the hardware and software we developed, as well as some of the highlights of what this technology can do for growers.
Wireless sensor networks typically consist of 'nodes' with multiple sensors connected to each node. In our case, we use sensors that can measure soil moisture, water pressure, flow rate, or a range of weather variables (light, temperature, wind, humidity, etc.). The nodes have a radio built-in for two-way communication with a computer. The computer runs the software (or graphical user interface) that is used to control the setup of the entire network and to configure irrigation parameters. Growers can use the information from these sensors to decide how they want to manage the irrigation of different crops. These decisions can be programmed into the graphical user interface. Although our prototype nodes had relays built in that could be used to automatically open and close irrigation valves, the commercial system that will be released soon has a different configuration.

Decagon Devices, our commercial partner, will commercialize the PlantPointTM system. This system consists of three different types of nodes, which have distinctly different functions: monitoring nodes, control nodes, and gateway nodes. Since the nodes are powered by batteries, they can be placed in production areas where power is not available. Monitoring nodes can be used to connect up to five sensors. Control nodes accommodate only a few sensors, but can be used to control up to four separate irrigation zones. The gateway node relays information between the control nodes, monitoring nodes, and the SmartBase station. The SmartBase, a simple computer, generates a website that can be accessed on-line. This website serves as the graphical use interface.

The website can be customized with a map of a specific greenhouse, nursery or farm and detailed information from each of the nodes can be seen in graphs that summarize the most important information from each node. The data is presented in a way that helps growers use that information to make better informed decisions about irrigation scheduling. The website is also used to configure the irrigation control nodes. Growers can program whether they want to irrigate based on a set schedule, based on substrate water content, or other parameter. The hardware and software are designed for maximum flexibility to accommodate the needs of different growing operations. One crucial feature is scalability: growers can start with a small system and gradual expand that system over time. This will hopefully encourage growers to adopt this new technology, starting with a small system to determine whether it is cost-effective and, if so, to scale up.

Among the benefits of wireless sensor networks for irrigation management are the following:

Provide growers with real-time information: Sensor networks provide growers soil moisture and environmental conditions for their own greenhouse. Since the data can be seen on-line, access to this information is easy. We have learned that most growers make much better irrigation management decisions once they have access to data collected in their own operation. Seeing the impact that their irrigation decisions have on substrate water content makes it easy to improve on standard practices.

Precision Control of Irrigation: We have achieved between a 40 and 84% reduction in irrigation water applications with soil moisture sensor-based irrigation control. Although reductions vary from operation to operation, we have consistently seen large reductions in irrigation water use. For one of our nursery growers, a 50% reduction in irrigation saved over 43 million gallons of water, and $6,500 in pumping costs in 2012. In parts of California, where water is expensive, the cost of this 43 million gallons of water would have been at least $100,000. In this case, the return on investment for the $48,000 sensor network would have been less than six months.

Impact on Water Availability: Some greenhouses are limited by the capacity of their well or pump, or by the time it takes to irrigate all crops. Water availability and irrigation time can limit the amount of plants that can be grown. One nursery grower was able to install an additional 30-acre tree production area, simply based on the amount of water he saved elsewhere using sensor-based irrigation.

Increased Yields and Quality: Growers can use these sensors as a tool to refine their growing practices for increases in yield and quality. A snapdragon cut flower grower was able to make more timely irrigation decisions through the use of sensor networks in his greenhouse production. Since these plants were grown in a recycling hydroponics system, water savings were not a concern. But better irrigation management increased the yield of snapdragon cut-flowers by 30%, while also increasing the quality. Increases in yield and quality paid for the sensor network in 16 months.

Reductions in nutrient leaching: Water moves fertilizer through the soil or substrate, so irrigation management is a key part of nutrient management. Excessive irrigation leaches fertilizer from the substrate. The leaching of fertilizer from the substrate may than require additional fertilizer applications. We found that sensor-based irrigation control can greatly reduce fertilizer leaching, cutting the required fertilizer applications by 50%. We have estimated that just in the state of Georgia, US, this could save ornamental growers up to $10,000,000 per year in fertilizer costs. Fertilizer savings can be achieved regardless of whether water-soluble or controlled-release fertilizer is used. When using water-soluble fertilizer, less irrigation will automatically reduce fertilizer applications. When controlled-release fertilizers are used, better irrigation management will reduce the amount of fertilizer that is leached and thus reduce the need for additional fertilizer applications. Reduced leaching can also help growers meet environmental regulations. For example, growers in the states of Maryland and Florida need to demonstrate reductions in nutrient use as a key part of complying with state-mandated nutrient management regulations. A reduction in leaching also reduces the runoff from herbicide, fungicide and systemic pesticide applications.

An alternative to plant growth regulators: Plant growth regulators are widely used in the greenhouse industry to control plant size. Research with poinsettias has shown that sensor-controlled irrigation can be used as a non-chemical alternative to the use of PGRs. Sensor controlled irrigation can be used to expose plants to a controlled water deficit. This can be used to reduce the stem elongation rate when plants get too tall. Using sensor-controlled irrigation systems, growers can maintain a lower substrate water content for as long as needed to get the amount of growth regulation needed. Additionally, the effect of water deficit quickly ends after substrate water content is increased again, in contrast to using PGR's. The use of non-chemical growth regulation can also be used for marketing purposes, since consumer concern over the use of agro-chemicals is steadily increasing.

Disease management: Sensor-based irrigation decreased disease-related plant losses in Gardenia jasminoides from 30% to virtually zero. On top of that, the production cycle was shortened from 14 to 8 months, reducing the required inputs (labor, fertilizer, fungicides etc.). Combined, this resulted in a 2.5-fold increase in annualized profit, with a payback period of less than two months on the sensor network (approximately $6,000). Although perhaps unusual, this illustrates the compounded economic benefits of increases in efficiency, yield and disease reduction, as well as increased turnover of production space.

Overall Environmental Benefits: We projected environmental benefits with a variety of scenarios for ornamental growers in the US. For example, using a 50% industry adoption rate in the ornamental industry alone, a 50% reduction in water would save enough water for 400,000 households a year, reduce energy usage equivalent to removing 7,500 cars annually, and prevent 280,000 kg of nitrogen and 180,000 kg of phosphorus from entering the environment. So the benefits of this technology go well beyond individual growers. Society-at-large benefits as well.

Keywords: *greenhouse, profitability, soil moisture sensor, sensor networks, water*

ONLINE PROFESSIONAL IRRIGATION SCHEDULING SYSTEM FOR GREENHOUSE CROPS AND FRUIT TREES

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Abstract

A knowledge-based system, for online precise irrigation scheduling (OpIRIS) using advanced results from research projects on water and fertilizers productivity in greenhouse hydroponic crops, is build. Firstly, a compilation of information for creating a database that provides irrigation decision-makers at farm level with practical information on water and fertilizers productivities as affected by irrigation-related technologies and scheduling methods is developed. To visualize the above results a friendly graphic user interface is designed. Thus, any farmer can have the opportunity to auto-evaluate his agronomic performance as compared to similar cases applying different technologies and using different management strategies. Then, an algorithm is built in a web based application to recommend on precise irrigation scheduling (doses and frequency) for hydroponic crops under greenhouses and for fruit trees in open field. Microclimate sensors installed in the greenhouse are connected to device-to-web data loggers which feed a respective sensor data database. The algorithm module calculates the crop transpiration rate based on solar radiation, air temperature and relative humidity measurements and taking also into account measurements of substrate water content, nutrient solution supplied and drained and estimations of crop leaf area index, indicates when to irrigate and how much nutrient solution to apply. Furthermore, based on the above data, an evaluation of the irrigation performance is given and recommendations to improve the water and nutrients use efficiency are supplied. For fruit trees, the irrigation doses and frequency are determined by a water balance algorithm that is frequently adjusted by local reference evapotranspiration, soil moisture readings and trunk diameter variations. An additional management algorithm has been developed to integrate the results into the farm's decision making procedure. It considers the hydraulic capacity of the local irrigation system such as the total available water and the total number of sectors as well as the farmer's availability to irrigate and he's priority level for each sector.

Keywords: *expert system, water use efficiency, drainage rate, crop transpiration*

GROWTH AND ORNAMENTAL QUALITY OF POTTED BOUGAINVILLEA GENOTYPES GROWN IN TWO SHAPES UNDER DEFICIT IRRIGATION

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Abstract

Deficit irrigation (DI), that involves the application of water at a rate and volume lower than the evapotranspiration rate throughout the whole growth period, may be used in potted ornamental plants to improve plant quality. The interest in DI has primarily centred on water savings and/or to control excessive vegetative growth mainly in fruit trees and vegetables, whereas its application to ornamental crops has received limited interest so far. Bougainvillea is a genus of flowering plants widely used in the arid landscapes due to its high adaptability in different agro-climatic regions. Despite the importance of the Bougainvillea in floriculture production, no published data is available on the effects of different levels of DI on agronomical parameters and ornamental quality of Bougainvillea. The aim of this study was to determine the effects of three irrigations treatments on the growth responses and ornamental value of Bougainvillea genotypes, trained to two canopy shapes. Plant growth, ornamental quality, mineral composition and water use efficiency, were measured during the growing cycle. The experiment was conducted glass-zinc-coated steel greenhouse situated at the Experimental Station of the University of Naples Federico II, South Italy. Rooted cuttings of three flowering potted Bougainvillea genotypes, (B. glabra var Sanderiana, B. x buttiana 'Rosenka', B. 'Aurantiaca') were transplanted on March 1st, into pots containing peat moss and placed on troughs, with a plant density of 6 plants·m-2. Bougainvillea plants were grown in two canopy shapes: globe and pyramid. Treatments, arranged in a randomized complete block design with three replicates, were defined by a factorial combination of three irrigation levels based on the daily water use (100%-C, 50%-MDI, or 25%-SDI), three Bougainvillea genotypes, and two canopy shapes. The shoot, total dry biomass, leaf number, leaf area, and macronutrient concentration decreased in response to an increase in water stress, with the lowest values recorded in the SDI treatment. The percentage of total dry biomass reduction caused by irrigation level, was lower in B. x buttiana 'Rosenka', compared to B. glabra var Sanderiana and B. 'Aurantiaca'. At the same date, the flower index increased in response to an increase in water stress, with the highest values recorded under both MDI and SDI for B. x buttiana 'Rosenka'. The MDI treatment can be used successfully in Bougainvillea to reduce water consumption while improving the overall quality and WUE, whereas the genotypes B. glabra var Sanderiana and B. x buttiana 'Rosenka' could be considered suitable for pot plant

production. These results can play an important role for the ornamental industry, which is very interested in selecting tolerant genotypes and suitable shapes under water stress conditions, and to evaluate the DI as a useful technique to save water without affecting the economic value of the plant.

Keywords: *flower index, mineral composition, water use efficiency, water stress.*

SOFT- AND HARD-SENSORS FOR ADVANCED CONTROL OF FERTIGATION IN SUBSTRATE CULTIVATION OF GREENHOUSE AND NURSERY CROPS

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Abstract

Water is generally applied in excess to greenhouse and nursery crops, particularly when they are grown in substrate (soilless) culture, where the leaching fraction (the ratio between water leached and water applied) ranging from 30 to 50%. Over-irrigation results in water wastage and environmental pollution due to the leaching of fertilisers and plant protection products. A major cause of over-irrigation is inadequate scheduling, which often is based on grower's experience rather than on accurate assessment of crop water requirements. Leaf transpiration is the primary process affecting plant water uptake and hence its knowledge is necessary to determine actual crop water needs. Either hard-sensor (i.e. soil moisture sensor) or soft-sensor can be used for irrigation scheduling in substrate culture. Hard-sensors consist of soil moisture sensors or gravimetric while soft-sensors implement crop evapotranspiration models based on weather conditions. The application of closed soilless growing systems, where the drainage water is captured and reused, can reduce the consumption of water and fertilizers and the environmental pollution. However, the application of closed systems is scarce on a commercial scale as the management of fertigation is much more difficult in these systems compared to the open (free-drain) systems. Along with the risks consequent to the possible diffusion of root diseases, the salinity of irrigation water represents the main difficulty for the management of closed growing systems.
The paper summarizes the main results of a series of experiments conducted in the last 8-10 years at the University of Pisa and at CRA-VIV (Pescia, Italy): i) to develop and test some simplified models of crop evapotranspiration in some vegetable or ornamentals species; ii) to determine the effects of implementing different irrigation scheduling methods on heterogeneous container ornamentals; iii) to explore the influence of different fertigation strategies on the water and nitrogen use efficiency of substrate culture of greenhouse tomato conducted under saline conditions. How these results have been implemented in decision support systems for greenhouse and nursery growers is discussed.

Keywords: *crop modelling, decision support systems, irrigation, soilless culture, water and nutrient use efficiency*

DECISION SUPPORT SYSTEM- DSS- FOR IRRIGATION MANAGEMENT IN GREENHOUSES: A CASE STUDY IN CAMPANIA REGION

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Abstract

In Mediterranean Countries the proper management of water resources is important for the preservation of actual production systems. The possibility to manage water resources is possible especially in the greenhouses systems. In Campania region protected crops (greenhouses and tunnels) have a considerable economic importance both for their extension in terms of surface harvested and also for their production in terms of yields.
Agricultural production in greenhouse is closely related to the micro-climatic condition but also to the physical and agronomic characteristics of the soil-crop system. The protected crops have an high level of technology compare to the other production systems, but the irrigation management is still carried out according to empirical criteria.
The rational management of the production process requires an appropriate control of climatic parameters (temperature, humidity, wind) and agronomical inputs (irrigation, fertilization). All these factors need to be monitored as well is possible in order to identify the optimal irrigation schedule. The aim of this work is to implement a Decision Support System -DSS- for irrigation management in greenhouses focused on a smart irrigation control based on observation of the agro-climatic parameters monitored with an advanced wireless sensors network.
The study is conducted in a greenhouse farm of 6 ha located in the district of Salerno. In the farm there are seven plots cropped with rocket.
Preliminary a study of soils proprieties was conducted in order to identify spatial variability of the soils in the farm. So undisturbed soil samples were collected to define chemical and physical proprieties; moreover soil hydraulic properties were determined for two soils profiles deemed representation of the farm. Then the wireless sensors, installed at different depth in the soils, determined volumetric water content (VWC) by measuring the dielectric constant of the soil using frequency domain technology (FDR).
The data acquired real time were used to determine water balance with a physically based model Hydrus 1D. The results show how the model is able to identify the optimal irrigation schedule as function of soil proprieties and crop needs.

Keywords: *irrigation, DSS, rocket, water content*

EFFECT OF IRRIGATION REGIME AND NITROGEN FERTILIZATION ON WILD ROCKET

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Abstract

In Italy, the cultivation of wild rocket [Diplotaxis tenuifolia (L.) DC] is still growing thanks to the increase of the market of the minimally processed vegetables that requires innovative products and high quality. The cultivation is carried out mainly in a protected environment. Therefore, although the rocket does not require high water volumes because of its short growing season, the water supplies occur only through irrigation. In the view of increasing water demand by other sectors, and expected reduction of water availability in the future, it is necessary to adopt water management strategies which aim at water saving while maintaining satisfactory levels of production, good quality and reduced environmental impact (i.e. deep percolation and fertilizers leaching).

The understanding of the interactive effect of water and nitrogen (N) availability, associated with the ability of crops to efficiently use these resources, is a crucial issue to improve wild rocket yield and quality, particularly leaf nitrate content, as the rocket is among the vegetables that accumulates large amounts of this compound harmful to health.

This study focused on the interactive effect of irrigation regime and nitrogen supply, with the aim to ensure economically sustainable production levels and high quality features, as well as to increase the water use efficiency (WUE) and nitrogen use efficiency (NUE).

The research was carried out during November 2014 – April 2015 at the "Troyli" farm, located in Basilicata region, southern Italy, on wild rocket grown in a plastic greenhouse under four irrigation regimes (supply of 75, 100, 125 and 150% of the crop evapotranspiration-ETc, respectively named I75 - I100 - I125 and I150) and two N levels (60 and 120 kg ha-1 N, respectively named N60 and N120).

There were four harvests. Yield, morphological and quality parameters were assessed.

The irrigation regime and the N level affected the production traits of the wild rocket. The water supply 100% of ETc (25% less irrigation in respect to the irrigation supply of the farmer) was the best irrigation regime for production. The highest dose of N provided the higher yield, but also the higher leaf nitrate content. In addition, in

the third and, mainly in the last harvest, a negative effect of nitrogen supply was observed on yield of less watered crop (I75).
The results of this research confirm that proper irrigation management and adequate N fertilization are two factors crucial to save resources and to produce wild rocket of good quality.

Keywords: *WUE, NUE, water supply, nitrogen supply, nitrate.*

APPLICATION OF THIAMETHOXAM THROUGH THE NUTRIENT SUPPLY SYSTEM IN A GREENHOUSE HYDROPONIC CULTIVATION OF CUCUMBER

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Abstract

Nowadays, there is a large demand for fresh fruits and vegetables and as a result, producers are forced to make a use of chemicals widely, in order to control predators. The most popular group of pesticides are neonicotinoids. A significant negative effect of neonicotinoids is their contribution to the huge reduction of bee populations all over the world, and they are also responsible for many other environmental problems in nature. They are still used, in fruits and vegetables mainly by foliar application, despite the fact that they banned in EU. The use of neonicotinoids is frequent and unfortunately, very few greenhouses with hydroponic systems use neonicotinoids by application via the nutrient solution as an alternative method. On the other hand, it is well known that substrates such as zeolite have the ability to adsorb and desorb gradually the elements of the nutrient solution for a long time, reducing the losses of the using fertilizers. However, the limited knowledge about the fate of plant protecting systemic substances after application in substrate with zeolite, is the main factor limiting a broad adaptation of this alternative method.
In this study the ability of thiamethoxam as a neonicotinoid systemic insecticide following application via the nutrient solution in substrate-grown cucumber crops to control the whitefly population caused by Trialeurodes vaporariorum was investigated. A local cucumber landrace was used to assess the behaviour of thiamethoxam in three different mixtures of substrate, using zeolite and perlite in six different treatments. The experiment was conducted at the Technological Educational Institute of Epirus, near Arta of Western Greece under greenhouse conditions using an open hydroponic system. Thiamethoxam application at a dose of 0.15gr/L-1 via the nutrient solution took placed twice, particularly on transplanting and 35 days later.
The first results indicated that thiamethoxam when applied in plants with zeolite was controlled better the whitefly, concerning the other treatments. The zeolite had a positive effect on plants development compared to other substrates and the use of zeolite had led to improved water use efficiency (WUE).

Keywords: *neonicotinoids, zeolite, perlite, water use efficiency*

NEW TOOL FOR SUSTAINABLE IRRIGATION MANAGEMENT IN GREENHOUSE CONDITIONS BASED ON HYPERSPECTRAL CAMERA

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Abstract

Agricultural practice requires a precision irrigation in emerging greenhouse management of water resources, for improving yield profitability and productivity and at the same time, decreasing the financial costs for water and energy consumption. Much progress has been made on optimizing water supply based on numerous methods for scheduling irrigation, such as solar radiation or substrate moisture. However, only a few methods use plant-based physiological indicators to detect plant water stress. Some genetic and biochemical plant approaches are time consuming and often fail to fully predict the performance of new lines in the field. The aim of this work is to study the possibility of using crop reflectance measurements for scheduling irrigation and crop water stress detection in greenhouse crops. Hyperspectral camera that measures reflectance from 400 to 1000 nm is able to collect leaf reflectance data from any off-nadir angle in order to use plant-based physiological indicators to detect plant water stress. The current paper briefly describes the most important technical specifications of the aforementioned ground-based remote sensor and the method of making precise plant reflectance measurements inside the greenhouse environment. The most important points in order to acquire an accurate image are summarized. Moreover, the spatial-spectral camera's resolution set a significant challenge to data analysis. Thus, classical supervised or unsupervised learning algorithms are adjusted in this technique in order to optimize fast computation of massive datasets. The method was tested for drought stress, applied to tomato plants in hydroponic greenhouse conditions by subjecting two irrigation treatments (control and stress plants).

Keywords: *water management, water stress detection, reflectance, hyperspectral*

OBSERVATIONS ON THE SUBSTRATE ELECTRICAL CONDUCTIVITY MEASUREMENTS USING GS3 SENSORS IN PERLITE

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Abstract

A new sensor for the measurement of electrical conductivity (EC) and moisture content, specifically designed for soilless substrates, has been released (GS3, Decagon Devices). The Hilhorst equation has been proposed as a tool to convert the measured bulk EC (ECb) into the pore EC (ECp, the EC of the solution in the pore spaces of the substrate). A test was carried out to verify the ability of the GS3 sensors to measure changes in the substrate EC under realistic cultivation conditions. Pots, containing tomato plants growing in perlite, were subjected to irrigation for about four weeks with a schedule set to have a leaching fraction of about 90%, which enabled the maintenance of very similar EC in both the root zone and the drainage solutions. A low and a high EC nutrient solution (EC = 2.4 and 4.1 dS/m, respectively) were used in the first and the second half of the test, respectively. The EC of the leachate, used as a measure of the real substrate ECp (ECpreal), the ECb measured by the GS3 sensors and the resulting ECp calculated with the Hilhorst equation (ECpHilhorst) were recorded during the test. The three parameters (ECb, ECpreal and ECpHilhorst) all showed the trend of increasing salinity in the substrate. However, both ECb and ECpHilhorst resulted in different values, in absolute terms, compared to the ECpreal provided by the measurement of the leachate. In particular, the ECpHilhorst values were always lower than ECpreal (0.60 vs 2.48 dS/m and 1.10 vs 4.68 dS/m, on average, respectively in the first and second half of the test). However, the ECpHilhorst was correlated in the tested EC range with the real ECp in the substrate (ECpreal = 4.2815×ECpHilhorst - 0.0766, R^2=0.99). According to our results, it seems that GS3 sensors used in perlite are not able to provide accurate values of ECp simply by applying the Hilhorst equation. However, the values provided by the sensor are correlated with the real ECp of the substrate; therefore, using a proper second-step equation can help to convert the obtained value into the real ECp of the substrate.

Keywords: *soilless growing media, soil moisture sensor, EC*

This work has been supported by project "Efficient Irrigation Management Tools for Agricultural Cultivations and Urban Landscapes" (IRMA) - European Territorial Cooperation Programmes (ETCP), GREECE-ITALY 2007-2013.

SESSION:

MODERN STRATEGIES FOR WATER MANAGEMENT FOR OPEN FIELD CROPS

MODERN STRATEGIES FOR WATER MANAGEMENT FOR OPEN FIELD CROPS

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Extended Abstract

Water is an essential resource for crop and livestock production. Climate change is generating variation in rainfall forcing farmers to rethink how to produce their crops and manage their farms. To relieve negative impacts of climate change on agriculture due to water scarcity, new management strategies at the farm level need to be identified. It is also essential to establish channels and mechanisms to make this information available to the farmers which intend to adapt their businesses in economically viable ways. Going beyond the "easy" solution of using more water for irrigation, the agronomic research has broadcasted innovative approaches and adaptive strategies to cope with water scarcity at farm/local level.
The aim of this keynote is to discuss these issues in the specific context of IrriMed2015 to seek practical solutions to be adopted for solving on-farm problems by bridging the gap between the practice and agriculture science. Merging the on-farm experience with improved understanding is the first step to reliable improvement in yield through adapted management. This key-note offers an overview of current and potential adaptive strategies at farm level for reducing the impact of water scarcity on farm productivity.
Water shortage is a major abiotic factor limiting crop and livestock productions in Mediterranean region and its incidence is expected to increase with climate change. Areas in the Mediterranean are likely to suffer higher temperatures, more rainfall variability and greater frequency of extreme events (IPPC, 2007). The arid regions face the double problem of less and more erratic rainfall, and higher temperatures that surpass the threshold limits for major crops. By contrast, positive impacts are expected in northern Europe with climate change, particularly increased water supply and reduced water demand. Apart from the geographical location, the impact of climate change on farm production will also depend on farm characteristics and on farmers' capacity to change management and adapt to new conditions.
Water sources for crop production at the farm scale are rainfall and irrigation. Rainfed crops grow mostly during the rainfall season, but can grow also from stored water in the soil during the dry season. Water is essential to extract nutrients from the soil and transport them to the rest of the plant. Water is evaporated from the plant into the air through the stomata (transpiration) through which CO2 is absorbed to store carbohydrates (photosynthesis) and grow. The hotter, drier and windier the air is

(higher evaporative demand), the faster the water is lost through transpiration. Not all rainfall is used in plant growth and transpiration. Part of the stored water in the soil is lost through evaporation from bare soil between the plants; and part of the rain or irrigation water is lost by runoff and deep percolation, although it may be used down-stream by other farmers. The water that remains stored in the soil is available to roots for crop growth and transpiration.

The damaging effect of a drought period will depend on its duration, on how much water is stored in the soil and the proportion that the crop can access, how fast it is used or lost, and the crop development stage at that time. Time scale includes weeks to months, cropping season or years. Farmers can change the management of their systems to reduce drought impacts in the production e.g. adopting strategies to reduce runoff or percolation.

Previous studies have identified how to reduce the negative impact of climate change on water scarcity. In general, strategies coincide with those recommended for current drought prone areas, as it is assumed that these strategies will continue to be effective in relative terms under climate change scenarios in the future.

Proposed actions go from molecular transformation of crops (e.g. transform rice plants into C4 plants) to the construction of new irrigation infrastructures. This keynote focuses on adaptive strategies at farm level, i.e. changes in crop management practices that lead to a reduction of the impact of water scarcity on farm productivity. Strategies at molecular to plant level are not discussed but some aspects are mentioned when referring to cultivar type chosen by farmers. Strategies dealing with irrigation at scales above the farm are not included either. In general, strategies intended at increasing water availability in rainfed conditions will benefit also in irrigated systems as rainfall provides part of the water consumed by irrigated crops. To increase availability, strategies will either aim at reducing water losses by reducing runoff, drainage and/or soil evaporation, or at increasing the capacity to store the water that may be used by the crop.

Any management strategy that increases soil water infiltration (and therefore reduces runoff), or that reduces soil evaporation, will increase water stored in the soil. These strategies include: conservation agriculture (defined as a combination of minimum soil disturbance, maintaining of residues on the ground and crop rotation), stubble used for mulching and reducing in turn soil evaporation, early ground cover after the break of the rainy season which reduces the soil evaporation in similar way than mulching, crops or cultivars with deep root systems, effective weed control. Deep tillage may be required to increase water infiltration if a hard layer is present in the soil profile.

Other strategies are focused to increase soil stored capacity of water. The stored available water content depends greatly on the soil texture and structure. The texture is fixed but the structure can be improved by increasing soil organic matter or by reducing soil compaction. Strategies that improve the rooting system will improve access to the stored water. These strategies include: management of crop residues for increasing the soil organic matter, controlled traffic, crops having high rooting ability to colonize the soil, fallow (to store water rainfall of that season in the soil).

In irrigated agriculture, water scarcity concerns water availability and reliability and its sustainable use. Strategies specifically related to irrigation and dealing with water scarcity includes increasing water supply and reliability, choosing the irrigation

system, maintenance of current irrigation system, improving uniformity of water distribution and of application efficiency. Other actions could be the development of new sources of water, the access to underground water, the reduction of water losses in irrigation systems (mainly the runoff and percolations in sprinkler irrigation), the subsurface irrigation, the plastic mulching.

Finally, a series of management options allow to increase irrigation efficiency. Irrigation efficiency may be increased by improving distribution uniformity and/or application efficiency. In the last decades, modernization of irrigated systems at farm and scheme levels has increased irrigation efficiency significantly (minimizing losses and improving uniformity) but, rather than resulting in more reliable annual allocation (the general objective), the saved water had resulted in an expansion of the irrigated area. In this case, the good practices are: uniformity of the irrigation systems (laser levelling of soil surfaces), supplemental irrigation, alternate furrow irrigation, irrigation scheduling.

There are no systematic on-farm evaluations of current practices for their "effectiveness" increasing water productivity. The impact of some strategies can be assessed through the application of hydrologic principles, water balances or other models if they are calibrated at the local conditions. Nevertheless, the evaluation of the effectiveness will often require understanding the impact at higher scales (irrigation scheme and watershed).

However there are limits to the improvement of water productivity on farm, not necessarily associated to water scarcity. There is a need to know these limits in order to avoid inadequate efforts. Benchmarks for water productivity are realistic references that can be considered as objective for farmers. For example, local benchmarks could be the values of water productivity or irrigation efficiency obtained by the best local farmers.

Economic and environmental risks associated to any strategy must be well understood and evaluated for resulting viable options. These risks may vary between socio-economic and environmental conditions. Ideally, strategies should not result a problem for farmers in term of labor or large capital investments nor should they damage the environment.

Keywords: *mediterranean region, climate change, agronomy, dry-farming system, water resources*

GROWTH, WATER AND NITROGEN USE EFFICIENCY UNDER DRIP IRRIGATION ON WHEAT GROWN ON AN ARID REGION

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Abstract

Irrigation water is limiting for crop production in arid and semi arid region. Modern irrigation system such as drip irrigation are widely used in Egypt and also used in the countries especially with limited irrigation water resources. Drip irrigation provides the efficient use of limited water with increased water use efficiency (WUE). Application of nitrogen (N) to wheat is needed to ensure the N is available throughout the growing season due to its important role in promoting both vegetative and reproductive growth. Field experiment was carried out during season 2010 and 2011 at a private farm located at a newly reclaimed sandy soil at El-Sadat district El-monofia governorate, Egypt to study the effect of four nitrogen fertilizers levels (i.e., 0, 40, 60 and 100 kg N /fed.), two N fertilizer type [urea 33.5 N %) or ureaformaldehyde (38%N)] combined with two irrigation regimes at different soil moisture depletion (FC) (I1=80% of FC or I2=40% of FC) on wheat crop irrigated by drip method. The nitrogen fertilizer as urea was injected into irrigation water by an injection pump. Available nitrogen in soil depths 0-20, 20-40 and 40-80 as well as nitrogen uptake by straw and grains yield were determined, also Grain Nitrogen Recovery (GNR). The results showed that application of water quantity at I1 through drip irrigation along with 100 kg N /fed., from two sources of nitrogen recorded the highest yield of shoot and grain and the nitrogen content as well as nitrogen use efficiency compared with the other rate and levels of nitrogen and irrigation, respectively. Also, WUE increased with irrigation I1 and nitrogen levels and reached the highest values at 100 kg N fed. as urea fertigation compared with ureaformaldehyde.

Keywords: *levels of irrigation, ureaformaldhyde, water use efficiency, nitrogen fertilizer fe=0.42 ha*

EFFECT OF SPLIT-ROOT-SYSTEM WATER STRESS ON PHYSIOLOGICAL AND MORPHOLOGICAL ASPECTS OF EGGPLANT (*SOLANUM MELONGENA L.*)

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Abstract

In view of increasing water demand by other sectors, and expected reduction of water availability in the future, it is necessary to adopt water management strategies which aim at water saving while maintaining satisfactory levels of production. One of these strategies is to improve water use efficiency through the application of deficit irrigation (DI) which deliberately sustains some degree of water deficit and yield reduction. The expectation of these strategies is that any yield reduction will be not significant as compared with the benefits gained from water saving.
Partial root-zone deficit irrigation (PRD) is a DI technique to save irrigation water without much yield reduction. In fact, several authors report that when only part of the root system undergoes water-stress, abscissic acid (ABA) may be produced. This is transported through the xylem towards the leaves and reduces stomatal opening. On the contrary, poor root function reduces the production of cytokinins which are responsible for stomatal opening. These two aspects may combine to reduce stomatal opening and, consequently, gaseous exchange between the leaves and the surrounding environment.
This study focused on the effect of DI via PRD on gas exchange, assimilated distribution, yield, and water use efficiency (WUE), to acquire useful information for the possible application of this technique on eggplant crop.
Research has been carried out in southern Italy to study the split-root water stress effect on some physiological and morphological parameters of eggplant (Solanum melongena L. cv Tania). Plants were grown in pots and the root system was divided into two equal halves by a plastic wall. The pots were put in open air and the soil surface was covered by a waterproof film to protect the soil from rain water. The following treatments were compared: 1) the entire rhizosphere (both halves) well watered during the whole vegetative cycle (WW); 2) half a rhizosphere well watered and the other half water stressed after the beginning of blooming until the end of the vegetative cycle (WS1); 3) half a rhizosphere well watered and the other half water stressed, 30 days later in respect to treatment WS1, and until the end of the vegetative cycle (WS2). It was adopted a randomized blocks layout with 5 replicates.
The results showed that stomatal conductance (gs), transpiration and assimilation rate (A) decreased at beginning of partial root water shortage cycle, but after the

first days of plant adaptation to the new situation, was observed a recovery in this parameters, mainly in A. The reduction of gs is likely to depend not only by the low water potential in the xylem but also by ABA and cytokinins produced by the stressed root system. The shoot/root ratio decreased in PRD plants, mainly in WS1. In PRD plants was observed a reduction in yield, by around 13 (WS1) and 9% (WS2) but, because of lower evapotranspiration experienced by these plants, the WUE increased significantly.
The application of DI via PRD at cultivation of eggplant can be an effective strategy to save water for this crop in areas where the water resource is limited.

Keywords: *deficit irrigation, water use efficiency, gas exchange, irrigation technique, root/shoot ratio*

THE EFFECTS OF POTASSIUM APPLICATION ON THE GROWTH, MEMBRANE PERMEABILITY AND NUTRIENTS UPTAKE OF YOUNG CORN PLANTS GROWN UNDER DROUGHT CONDITIONS

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Abstract

A pot experiment was conducted to determine the impacts of different potassium fertilizer doses applied to corn grown under water stress on plant improvement, chlorophyll formation, cell membrane permeability and some plant nutrient uptake. The experiment was designed as randomized blocks with three replications. In this research, three different irrigation levels (100%, 75%, and 50% of pot water capacity) with two different potassium doses (control, 100 ppm K+, and 200 ppm K+) were applied to corn plant.
This study was focused on effects of potassium fertilizer on young corn plant in water stress and dry conditions.
The dry matter yield of root and shoot, chlorophyll formation, and the nitrogen and potassium contents of the root and the shoot all decreased as irrigation water decreased and increased as potassium fertilizer applied increased. Phosphorus content of the root and shoot decreased as irrigation water applied decreased. Potassium fertilizer had no effect on phosphorus content of shoot and root. Membrane permeability of the leaves increased as irrigation water applied decreased and decreased as potassium fertilizer applied increased.

Keywords: *chlorophyll, irrigation, dry conditions, potassium fertilizer, water stress.*

ENHANCING POTATO DROUGHT TOLERANCE BY REGULATING POTASSIUM FERTILIZATION AND IRRIGATION IN BEKAA VALLEY-LEBANON

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Abstract

Potato, a cash crop in Bekaa valley, is grown on early spring. The crop is totally dependent on irrigation water with levels of application reaching 750 mm by the farmers. A trial on potato response to fertilization and irrigation was conducted using a complete randomized block design in dry sub-humid Bekaa valley at the experimental station of the Research Center for Environment and Development, Beirut Arab University, between April and July 2015. In parallel, observations and measurements were conducted on a farm using macro sprinklers and producing potato. Soil moisture status during the season, and in both locations, was concurrently monitored by inserting soil moisture sensors at 25 cm and 50 cm depth. In the Research Center, a table potato crop (Spunta) was fertilized using three levels of potassium: 150 (K1), 300 (K2) and 450 kg ha-1 (K3) on clay, neutral pH, slightly deficient in major nutrients Eutric Fluvisols. The control (K0) did not receive any potassium. All treatments received equally nitrogen (N=150 kg ha-1) and phosphorus (P2O5=150 kg ha-1). The crop, subjected to mild deficit irrigation (85% of ETc) starting from the shoot development stage, was irrigated with a drip system. Because of a relatively wet spring, the requirement for irrigation water was rather low. An overall amount of 270 mm was applied against 345 mm by sprinklers at the farmer level. There the soil moisture sensors indicated an excessive irrigation. The crop performance including growth characteristics and tuber yield was evaluated during three main phenological stages: mid-flowering (MiF), mass flowering (MaF), physiological maturity (PM) and the final yield was recorded and categorized at full maturity. The performance of the crop was further assessed by determining the chlorophyll content. Treatment K3 presented significantly higher chlorophyll content during the MaF and PM stages. Further at mid-day, the canopy temperature decreased significantly in K3 (29.6 °C) as compared to the K0 treatment (31.0 °C) which can indicate different response of plant's leaves to potassium level and its role in regulating the water use. The final crop yield significantly increased from 23 Mg ha-1 in K0 to 33 Mg ha-1 for K3. However, the tuber dry matter content (between 19.5% and 20%) was not significantly affected by the level of potassium, while, the average tuber weight and commercial tuber weight were significantly higher in K3. Continuous mild deficit drip irrigation allowed obtaining relatively steady and spatially homogeneous soil

moisture content throughout the season varying between 0.25 $m^3 \cdot m^{-3}$ before the irrigation and 0.45 $m^3 \cdot m^{-3}$ after the irrigation in the experimental station. In the farm, soil moisture systemically fluctuated and exceeded the measured by BOWEN Ratio evapotranspiration. Improved fertilization and irrigation practices using advanced monitoring tools resulted in better water productivity: 122 kg tubers produced by 1 mm applied in drip versus 107 kg tubers per 1 mm applied using sprinklers on the commercial farm. The addition of potassium fertilizers could ensure a greater tolerance and water saving of field crops to drought in dry sub-humid conditions.

Keywords: *field crops, evapotranspiration, good practices, balanced fertilization, water productivity.*

EVALUATION OF VARIOUS SENSORS FOR IRRIGATION MANAGEMENT IN URBAN LANDSCAPES

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Abstract

In many urban areas, landscape irrigation accounts for 50% or more of the total water use. Control technologies are available for reducing over-irrigation and include special features such as multiple programs and start times, rain delay and water budget. A variety of sensors can be connected to modern controllers in order to provide useful data and improve irrigation efficiency: rain sensors can suspend irrigation for a certain period after rain, soil moisture sensors allow irrigation only when soil moisture is bellow a pre-set threshold, pyranometers allow controllers to monitor solar radiation as a measure of evapotranspiration and continuously adjust the frequency of irrigation events, while evapotranspiration based controllers (ET controllers) use a series of meteorological data to calculate the actual ET at the site and use it to adjust irrigation. In this framework a field study was conducted at the Technological Educational Institute of Epirus (Arta, Greece) during the irrigation period (May-September) of 2014. The purpose was to investigate the water conservation potential of various scheduling approaches of controllers with and without the use of special sensors. Five treatments: a) irrigation controller using water budget periods (reference treatment); b) irrigation controller using water budget periods + rain sensor; c) irrigation controller using solar energy (as measured by a pyranometer) integration for continuous calculation of frequency; d) irrigation controller connected to soil moisture sensor and e) irrigation controller connected to Evapotranspiration (ET) + rain sensor were applied to tall fescue, a cool-season turfgrass, which is considered the most commonly used in North and Western Greece. The evaluation was based on applied water quantity measurements; fresh and dry cuttings weight and solar radiation reflectance (PRI and NDVI indices). The results indicated that the ET, Soil moisture and Solar Radiation sensors saved 35-40% of water when compared to a typical theoretically calculated constant irrigation schedule. The considerable savings for ET and Solar Radiation sensor treatments were not accompanied by any decline in growth or quality of the turfgrass. Soil Moisture sensor treatment showed no difference regarding growth and just a small difference regarding leaf area index when compared to the reference treatment. The conclusion is that the use of such sensors is strongly recommended as it is expected to lead to considerable water savings.

Keywords: *smart controllers, irrigation efficiency, turfgrass*

EFFECT OF MAGNETIC WATER ON YIELD AND FRUIT QUALITY OF SOME MANDARIN VARIETIES

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Abstract

The present study was carried out during the two consecutive seasons 2013and 2014 on 5 years old two mandarin varieties namely Balady and Fremont (Citrus reticulate Blanco) to elucidate the effect of magnetic water treatments on yield and fruit quality. Replicated filed experiments involving magnetically treated and non-magnetically treated water, saline water (832 ppm and 1280 were conducted at a private orchard located at Alsalehia Algadeeda, Alsharkia Governorate, Egypt. A magnetic treatment device with its magnetic field in the range of 3.5–136 mT was used for the magnetic treatment of irrigation water.The results indicated that irrigating the trees of the two mandarin varieties with magnetic water had significantly increased yield (kg/tree) in comparison to that of control. Maximum yield (Kg/tree) was obtained from mandarin varieties irrigated all over the growth seasons with magnetic water. In this regard Balady mandarin variety was superior to those of Fremont one compared with control. The increase in yield attained nearly 35% in comparison with controlThe physical and chemical fruit characteristics of the two tested mandarin varieties were significantly improved in response to irrigation with saline water treated with magnetic in comparison to control that was irrigated with saline water too. The use of magnetically treated irrigation water K but increased soil EC and available N and P. More studies are needed to declare the influence of magnetic water on thegrowth, yield and fruit quality of different citrus varieties.

Keywords: *citrus, balady, fremont.*

EFFECT OF PYRACLOSTROBIN ON TOMATO CROP UNDER SALINITY STRESS

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Abstract

Tomato for processing is a very widespread crop in the Mediterranean area where often there are problems of high salinity of irrigation water. It's well known that the high salinity creates physiological problems with considerable negative effects on production.
Pyraclostrobin belongs to a class of fungicide (strobilurins) having a broad spectrum of applications, with preventive, curative, translaminar and locosystemic properties. In the literature it is reported that strobilurins can affect the plant metabolism resulting in the increase of yield, dry matter, content of both chlorophyll and protein and delay senescence. In addition, it was observed plant water balance modification by reducing root water uptake, resulting in the postponement of soil dehydration, so it may contribute to yield enhancement. Because many effects of salt stress are comparable to water stress, we may speculate that Pyraclostrobin could alleviate detrimental effects of salinity on plants.
This study focused on the interactive effect of salinity and Pyraclostrobin application on tomato grown in pots under plastic tunnel. The objective was to investigate the complementary properties of Pyraclostrobin in the improvement of tomato physiological (SPAD, gas exchange, activity of antioxidative enzymes as SOD, CAT, POD, APX), yield and fruit quality responses under salinity.
A two-year research (2010 and 2011) was carried out in Basilicata region, southern Italy, on cv Coronel to compare two soil salinity levels - 1.0 (S0) and 5.4 dS m-1 (S1) - and two fungicide treatments - application of fungicides without strobilurins (F0); application of a strobilurin based fungicide (Cabrio® Duo) (F1). The treatments were arranged in a split plot design with seven replicates.
On overall, when plants are treated with Pyraclostrobin, a considerable increase in POD, APX and CAT activity occurred, whereas no significant changes were observed in SOD. Different extent of changes in enzyme activity was observed in the two parts of the plant: POD increased only in roots, APX in roots as well as in leaves, and CAT only in leaves. In some sampling date, the increase in antioxidant enzyme activities was higher in saline stressed plants.
The amount of chlorophyll, measured in SPAD units, did not differed between salinity levels, instead, F1 showed the increase of about 6%. Gas exchanges were influenced

by salinity level and fungicide treatments. In particular, S1 has shown values of net assimilation (A), transpiration (T) and stomatal conductance (gs) respectively of about 17, 26 and 22% lower than S0, while the water use efficiency (WUE) was not influenced. Pyraclostrobin reduced A and T by about 8%, and gs by about 17%.
Salinity reduced fruit mean weight by 19%, total and marketable yield by 25 and 21%, respectively, and increased fruit blossom-end rot (BER) by 57%. Among the qualitative parameters, salinity caused the increase of total soluble solids (TSS) and dry matter (DM) of the fruits by 22 and 20% respectively. Pyraclostrobin increased fruits mean weight by 6%, total and marketable yield by about 8% and reduced BER by 19%. The improvement in total and marketable yield caused by Pyraclostrobin was higher in the crop with salinity stress (11.6%) in respect to the non saline one (6%). The reduction in A caused by Pyraclostrobin seems contradictory with the yield increase, so further research is needed to study the physiological mechanisms involved when Pyraclostrobin was applied. In view of the positive effects observed with the application of Pyraclostrobin, it should be promoted its use in programs of protection of tomato crop, above all in areas with salinity problems.

Keywords: *solanum lycopersicum, strobilurin, antioxidative enzimes, gas exchange, yield*

INFLUENCE OF WATER QUALITY AND IRRIGATION REGIME ON MAIZE PRODUCTION

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Abstract

Many irrigated areas of the Mediterranean such as Apulia region have problems of high salinity of the irrigation water with a negative impact on soil fertility and on production. To limit these effects is necessary to minimize the supply of salt and promote leaching, using an adequate irrigation management, which may vary according to climatic conditions, soil type and crop management.
Yield results related to a two years trial of a grain maize crop, irrigated with furrow method and included in a four-year rotation (maize, sunflower, maize, wheat), are reported. This activity was carried out in Apulia, on a shallow red soil, resting on fissured calcareous rock, as part of multi-year research, with the aim to evaluate the influence of water quality and irrigation regime on the production of some crops and the possibility that the rain water could leach solutes brought with irrigation water. Ten treatments, resulting from the factorial combination of two types of water (fresh water with electrical conductivity-ECw- of 1.2 dS m-1 and brackish water with ECw of 5 dS m-1) have been compared, with the following seasonal irrigation regimes: i) 75% of the maximum crop evapotranspiration (ETc); ii) 100% of ETc; iii) 100% of ETc, plus 50% of the needs of leaching (LR), calculated as: LR = ECw / (5 ECe - ECw), where ECw = electrical conductivity of irrigation water (dS m-1); ECe = electrical conductivity of the saturated extract of the soil; iv) 100% of ETc, plus 100% of LR, calculated as previously indicated; v) 100% of ETc until flowering, and 75% of ETc until the end of the crop cycle.
It was adopted a split plot experimental design with four replications. Irrigation was performed when in the treatment irrigated at 100% of ETc, the matric potential of the water in the layer of soil explored by the roots was equal to 0.1 MPa, providing the irrigation volume necessary to bring the matric potential to -0.03 MPa. In the first year there was no difference of corn production attributable to the water quality; in the second year, however, due to the accumulation of solutes in the soil for three consecutive seasons, the yield of grain obtained in the plots irrigated with brackish water, compared to those obtained in the plots irrigated with fresh water, have been reduced by 33.3 % (6.8 vs 10.2 t ha-1). Moving from the lower irrigation volume, to the most abundant (seasonal volume of irrigation sufficient to satisfy, respectively, 75% and 100% of ETc, plus 100% of LR), as average of the two years, the yield of grain increased from 7.4 to 9.1 t ha-1.

Keywords: *deficit irrigation, yield, brackish water, leaching requirement, zea mays*

MODELING ENERGY SAVING IN OPERATION OF PRESSURIZED IRRIGATION SYSTEMS

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Abstract

In the most of the irrigation systems, pumping stations are equipped with constant rotational speed pumps causing to waste a lot of energy and water. Providing a method for regulating the operation of the pumps can improve the efficiency of water distribution and energy consumption. Utilizing of variable speed control strategy for the pumping stations can optimize the energy efficiency and maximize the service period with the minimum cost. In this study a variable speed pumping station designed for a 80 ha olive cultivated area in Qazvin - Iran for different growing seasons using Water GEMS model. Also dynamic model of pumping station developed in Simulink and variable speed results compared to constant speed results in a 10 years period. The results showed that the amount of water losses in a constant speed pumping station with a perfect design is about 10 up to 51 percent in the growing season with maximum water demand depending on the type and operation of station, whilst the use of variable speed pumping station decreases energy consumption with an approximately rate of 49 percent.

Keywords: *irrigation systems, pumping stations, variable speed control, energy efficiency*

SEASONAL MOISTURE VARIATION AT DEEP AND SHALLOW SOIL LAYERS IN A MEDITERRANEAN KIWIFRUIT ORCHARD

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Abstract

Kiwifruit (Actinidia spp.) is a highly water demanding crop which originate from habitats characterised by high humidity and only a moderate intensity of sunlight, however because of its good profitability it is roughly well distributed also in semi-arid Mediterranean areas with dry growing season (~ 500 mm rainfall per year occurring mostly during autumn-winter). Irrigation is therefore mandatory for optimal fruit growth and yield (~ 50 t ha^{-1}).

For saving water purpose, drip irrigation is widely adopted in Mediterranean area in fruit tree crops including kiwifruit which may require up to 12,000 m3 irrigation water a year. Despite that relatively high seasonal irrigation volume, vines often suffer drought events. Considering that drip irrigation is neither design not managed to irrigate deep soil layer (> 50 cm depth) and that drip irrigation method keep soil moisture close to field capacity (FC) only in the early 30-40 cm of soil, it could be hypothesised that the moisture of deeper soil layer progressively decline during the season being not affected by drip irrigation causing water deficit.

To test this hypothesis, soil moisture was continuously monitored using FDR probes (EnviroSCAN Sentek, Stepney, SA, Australia) at 10, 30, 50, 70 and 90 cm depth throughout the growing season at a mature kiwifruit orchard (Hayward, 625 p ha-1). Vines were drip irrigated (2 drippers a plant, 10 l h-1 discharge rate each dripper) based on ETC values according to ET0 data released by a local weather station and Kc previously used in the area.

Results clearly show the soil moisture oscillations due to water consumption (vine absorption and soil evaporation) and replenishment (irrigation) at the early 10-30 cm depth. At that shallow layer, soil moisture oscillations remained close to FC (~ 38%vol) during spring and early summer, while minimum values approached 20%vol during mid-summer which were promptly recovered through the daily irrigation.

Soil moisture at deep soil layer (> 50 cm depth) progressively declined during the season toward the minimum value of 20-25%vol (70 cm depth) and ~ 30%vol (90 cm depth) reached at the end of July were sited during the reaming growing season. At these depths the consumption/replenishment oscillations were not detected, and soil moisture recovered only upon rainfall occurred in autumn.

Hence it could be inferred that these deeper layer supplied water to the above layers. It could be concluded that drip irrigation (schedule) was not adequately managed causing a withdrawal of water from deeper soil layer. Implication of these soil moisture dynamics in term of various components of water footprint are discussed.

Keywords: *drip irrigation, deep soil layer, drought, actinidia.*

YIELD AND WATER-PRODUCTION FUNCTIONS OF LETTUCE UNDER FULL AND DEFICIT IRRIGATION REGIMES

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Abstract

The relative amount of water available to agriculture is declining worldwide due to the rapid population growth and the greater incidence of drought in recent years caused by climate change and different human activities. Deficit irrigation occurrence while maintaining acceptable yield represents a useful traits for lettuce production wherever irrigation water is limited. Lettuce (Lactuca sativa L.) cv. Corsica was grown in the field from May to July in order (1) to investigate the daily and seasonal evapotranspiration (ETc) of lettuce using drainage lysimeter, (2) to determine the crop coefficients (Kc) values and (3) to study the effects of deficit irrigation on growth, yield and water use efficiency (WUE). Treatments were: well-watered treatment receiving 100% of ETc (C), water-stressed treatment receiving 80% of ETc (WS1), water-stressed treatment receiving 60% of ETc (WS2), water-stressed treatment receiving 40% of ETc (WS3). Lysimeter measured crop evapotranspiration (ETc) totaled 422 mm, for total irrigation period of 81 days. Seasonal evapotranspiration (ET) of lettuce treatments, varied from 351 mm in the WS1 treatment to 305 mm in the WS2 treatment and 259 mm in the WS3 treatment, while in the control ET totaled 397 mm. Kc increased gradually from lower values of 0.20 to reach by the end of the cop establishment a value of 0.44. Crop coefficient increased after that to reach at the end of the rosette stage and head formation a value of 0.70 and 0.80, respectively. The maximum values of Kc (0.83-1.01) were obtained at the end of the season during the maturity period. Increasing irrigation deficit reduced the vegetative growth parameters (plant height, leaf number and leaf area index) with deficits WS2 and WS3 significantly worse than the control treatment. The highest yield was recorded in C and WS1, with no significant differences between treatments followed by WS2, while the lowest value was recorded under the severe water stress treatment. A yield response factor (ky) value of 1.17 was determined, and lettuce was found to be sensitive to water stress. The highest values of water use efficiency (WUE), was recorded on WS1 (18.8 kg m-3), followed by the C (17.8), WS2 (16.3) and finally WS3 (15.5) treatment. Applying 80% of ETc resulted in water saving, with the least yield reduction, making more water available to irrigate other crops, and thereby considered optimal strategies for drip-irrigated lettuce in the semi-arid climate.

Keywords: *crop coefficient, deficit irrigation, evapotranspiration, lactuca sativa l.; water use efficiency.*

NEW CYTOKININ PRODRUGS FOR DRIP IRRIGATION

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Abstract

Soil drying and re-wetting occurs at varying frequencies and intensities during crop production, and is deliberately used in water-saving irrigation techniques that aim to enhance crop water use efficiency. Soil drying not only limits root water uptake which can perturb shoot water status, but also alters root synthesis of phytohormones and their transport to shoots to regulate its growth and photosynthetic parameters. Alternate wetting (irrigation) of plants with phytohormone solutions can also improve yield, and is correlated with altered phytohormonal (including cytokinins) metabolism and signalling. Increased endogenous cytokinin (CK) content through irrigation with a cytokinin prodrug(s) has been studied. We discovered that it is associated with improved plant drought tolerance. From this reason, objective of this study was to determine metabolic and crop parameter changes associated with elevated CK flow into tomato and paper plants. Physiological analysis confirmed that the CK-treated plants had improved drought tolerance compared with the control plants. Specific metabolite changes over the course of drought stress and differential accumulation of CK metabolites in plants were identified using liquid chromatography-tandem mass spectroscopy. The metabolite profiling analysis detected several metabolites differentially accumulated in response to CK treatment or drought stress, which included different phytohormones, amino acids, carbohydrates, and organic acids. The accumulation of these metabolites could contribute to improved drought tolerance due to their roles in the stress response pathways such as stress signalling, osmotic adjustment, and respiration for energy production.

Keywords: *irrigation techniques, phytohormones, drought tolerance*

METHODS AND TECHNOLOGIES TO IMPROVE EFFICIENCY OF WATER USE

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Abstract

The competition for existing freshwater supplies will require a paradigmatic shift from maximizing productivity per unit of land area to maximizing productivity per unit of water consumed. This shift will, in turn, demand broad systems approaches that physically and biologically optimize irrigation relative to water delivery and application schemes, rainfall, critical growth stages, soil fertility, location, and weather. Water can be conserved at a watershed or regional level for other uses only if evaporation, transpiration, or both are reduced and unrecoverable losses to unusable sinks are minimized (e.g., salty groundwater or oceans). Agricultural advances will include implementation of crop location strategies, conversion to crops with higher economic value or productivity per unit of water consumed, and adoption of alternate drought-tolerant crops. Emerging computerized GPS-based precision irrigation technologies for self-propelled sprinklers and microirrigation systems will enable growers to apply water and agrochemicals more precisely and site specifically to match soil and plant status and needs as provided by wireless sensor networks. Agriculturalists will need to exercise flexibility in managing the rate, frequency, and duration of water supplies to successfully allocate limited water and other inputs to crops. The most effective means to conserve water appears to be through carefully managed deficit irrigation strategies that are supported by advanced irrigation system and flexible, state-of-the-art water delivery systems. Non agricultural water users will need to exercise patience as tools reflecting the paradigmatic shift are actualized. Both groups will need to cooperate and compromise as they practice more conservative approaches to freshwater consumption.

Keywords: *computerized irrigation, freshwater consumption, cooperation*

ANALYSIS OF TIME-SERIES MODIS 250 M VEGETATION INDEX FOR TREE-CROP SYSTEMS

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Abstract

MODIS archives provide time series of satellite observations covering a time span of 15 and 12 years using Terra and Aqua satellites, respectively. The scope of this work is to analyze characteristic and dynamics of tree-crop systems in some areas of the Mediterranean basin. We use two vegetation indices, EVI and NDVI, acquired from MODIS-Terra (MOD13Q1) and Aqua (MYD13Q1) in the period 2003-2014. First we filtered the raw time series to reduce noise due to undetected clouds combining Terra and Aqua observations of NDVI, then we extracted some phenological indicators such as Green-up, Maximum and Senescence. Finally, we analyzed these indicators to asses productivity and biomass as their variability. Results for the period 2003-2014 indicate a decrease (increase) in productivity for most of tree-crop systems test site. MODIS data due to their remarkable temporal frequency, inevitable for detailed analyses of vegetation dynamics and phenology at (sub) regional scales allow for explore the history of development of traditional tree-crop agricultural systems and the potential applications resulting from the use of these data to characterize the vocation of the territory. The results could be later used for landscape planning.

Keywords: *modis, whittaker smoother, phenology, tree-crop agricultural systems*

YIELD AND QUALITY RESPONSE OF WHEAT TO SALINE IRRIGATION IN THE MEDITERRANEAN ENVIRONMENT

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Abstract

Various saline irrigation levels have been applied to wheat with a line-source sprinkler method in the Mediterranean environment under the rain-shelter at Cukurova University in the years of 2009/10 and 2010/11. The objectives of the study were to determine the effect of saline irrigation water on wheat yield, yield components (plant height, thousand grain weight, harvest index, protein content and wet gluten content), water use efficiency (WUE) and irrigation water use efficiency (IWUE). Concentration of saline water which mixed with fresh water used in the first year experiment was between 2.15 and 4.17 dS/m. On the other hand, salt concentration of saline water for second year experiment was between 2.61 and 19.7 dS/m. Three different salt concentration levels (TA, TB, TC) have been established. Saline water was applied fully to the treatment TA, which was the closest to the sprinkler lateral, while less saline water was applied to the treatment TC that was the most distant from the lateral. The treatment TB, on the other hand, received both saline and fresh water. Irrigation program was set as the daily saline irrigation water to TA closest to the lateral according to the amount of rain fallen naturally. The results revealed that different irrigation water with different qualities affected dry matter yield, LAI, leaf water potential and grain yield. As the salinity level of the irrigation water increased crop water use and grain yield decreased. Increase in salinity of irrigation water resulted in a decrease in IWUE, but raised the total WUE. Depending on the treatments, IWUE values varied between 1.15 and 2.36 kg/m3 while WUE values were determined as in the range of 1.39 and 5.22 kg/m3. Salt levels in irrigation water were found to significantly influence the yield and yield components of wheat.

Keywords: *saline water, wheat, rain-shelter, line source sprinkler system*

A FIRST YEAR OF COMPARISON BETWEEN ORDINARY DRIP IRRIGATION AND SUBSURFACE DRIP IRRIGATION (SDI) IN A CV. 'GRECO B.' VINEYARD

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Abstract

First application of Subsurface Drip Irrigation (SDI) are more than 50 years old but only in the last two decades there have been found interesting solution for the previously unsolved problem of emitter plugging caused by root intrusion. That, combined to the increased pressure to conserve water resources, lead to a renewed interest to SDI. Four irrigation treatments were applied in a commercial vineyards of cv. 'Greco b.' on SO4, VSP trained and Guyot pruned, in the area of the 'Basso Tavoliere' (Province of Foggia – Apulia – Italy). The treatments consisted of: T100n (100% water consumption by plants - dripper line over the soil surface; control); T100sub (100% water consumption by plants - dripper line under the soil surface); T75sub (75% water consumption by plants - dripper line under the soil surface); T50sub (50% water consumption by plants - dripper line under the soil surface). Midday stem water potential (Ψstem) was measured as indicator of the water stress level of treatments. Vegetative-productive balance were evaluated through the Ravaz index. Many quantitative and qualitative parameters of grape production were evaluated, comprising polyphenols, flavonoids and catechins content in skins and seeds. Results show excessive vegetative behavior in the vineyard and especially for the T100sub. Treatmets T100n and T75sub are more equilibrate while T50sub appear to suffer the high water constraint. This is in accordance with contents of almost all phenols fractions with lowest values found for T50sub and highest contents for T75sub. It seems SDI could determine about 25% water savings without influencing negatively the grape quality of 'Greco b.'.

Keywords: *SDI, subsurface drip irrigetion, WUE, vegeto-productive indexes, grape quality.*

EFFECTS OF PARTICLE FILM TECHNOLOGY ON TOMATO UNDER SALINITY STRESS

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Abstract

Irrigated agriculture is dependent on adequate water supply and its quality. Water used for irrigation can vary greatly in quality, depending upon type and quantity of dissolved salts. They originate from dissolution or weathering of the rocks and soils, and by intrusion of seawater into the river and underground water resources. The problem of saltwater intrusion due to groundwater over-exploitation is one of the major threats in the coastal areas of Italy, as occurs in Apulia region, where the chronic water shortage forces farmers to use saline irrigation water.
Salinity is detrimental for many crops because of its negative effects on the physiology and production. The salinity tolerance, as well as the genotype, is influenced by several agronomic and environmental parameters as air temperature and relative humidity (RH). Thus, conditions leading to a reduction of transpiration, as lower temperature and higher RH, can contribute to greater tolerance to salinity. Thus, the techniques that reduce the transpiration rate and heat stress of the crops could have a positive effect on salinity tolerance. Among those there is the kaolin-based particle film technology (Pft) that employs a multi-functional, environmentally friendly material effective in pest control, mitigation of heat stress, and to produce fruit and vegetables of good quality. The presence of mineral particles over leaves and fruit surfaces interferes with physiological processes, mainly with heat and radiation balance and gas exchange.
Therefore, it was hypothesized that the Pft could contribute to increasing the salt tolerance. In consideration that the tomato, species moderately sensitive to salinity, is a major vegetable crops present in the areas of Apulia at risk of salinity, to verify the hypotheses, was investigated the effects of Pft on yield and quality, and water use efficiency of field grown tomato.
The research was carried out in three years on tomato for processing, irrigated with brackish water, in Southern Italy. Treatments were i) three salinity levels of irrigation water (Electrical Conductivity of water = 0.5, 5, and 10 dS m-1), ii) tomato plants treated or not with kaolin, and iii) two cultivars in each year, arranged in a split plot design with three replications.
The salinity increase caused the reduction in yield mainly for declining fruit weight,

but the fruit quality was better in terms of dry matter content and total soluble solids. In addition, salinity increased the blossom-end rot mainly on cultivar with elongated fruits.
Pft, overall, as average of three years, improved total (12.7%) and marketable yield (17.7%), fruit weight (8.1%) and harvest index (10.3%), and reduced fruit sunburn by 76.4%. In addition, kaolin contributed to the declining in insect attack to the fruit (58.7%), improvement in total solid soluble (6.2%) and redness (10.2% the skin and 16.6% the pulp) of fruits, and increased yield water use efficiency (Y_WUE) (19.7%). Furthermore, kaolin mitigated detrimental effects of salinity on yield, through a minor decrease, between the control irrigated with fresh water and the more saline treatment, as average of three years, in total (22.8%) and marketable yield (34.8%), fruit weight (21.1%), biomass water use efficiency (B_WUE) (22.9%) and Y_WUE (34.7%).
The use of kaolin-based particle film technology may be an effective tool to alleviate salinity stress in tomato production in Mediterranean environment.

Keywords: *salt stress, heat stress, yield, WUE, solanum lycopersicum l.*

THE DSS GESCON FOR MANAGING IRRIGATION AND FERTILIZATION IN VEGETABLE CROPS. APPLICATION IN PROCESSING TOMATO CROP IN SOUTHERN ITALY

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Abstract

The work illustrates the theoretical basis, the methodological approach and the structure of a new decision support system program (GesCoN) designed for the management of fertigation in vegetable crops. The methodological approach is based on daily water and N balance, considering the water lost by evapotranspiration and the N uptake by the crop as output and irrigation, net rainfall, N fertilization, N mineralization from soil organic matter as main inputs. The software calculates on a daily basis the availability of water and N into the root zone, and assesses when to start a fertigation event and the amount of irrigation water and N fertiliser that has to be applied in order to fulfill the water and N-crop requirements. The models used by GesCoN for the prediction of plant growth, including root apparatus geometry and its interaction with wet soil zones, N uptake as well as the approaches used for predicting N mineralization and the dynamics of N and water into the soil are also described. Water balance is done by estimating ET0 through Penman-Montheit or a calibrated Hargreaves model. ETc can be estimated by using the single or dual Kc approach. The flow-chart of the program and the basic information for its functioning are described. Calibration and validation including a fertilization management example for a processing tomato crop in a nitrate vulnerable zone are also reported.

Keywords: *evapotranspiration, N uptake, root geometry*

Editing by Chieco Sistemi srl
September 2015 - Italy

European Territorial Cooperation Programmes (ETCP) GREECE-ITALY 2007-2013

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