Conclusions and recommendations

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CONCLUSIONS AND RECOMMENDATIONS

In this session some conclusions and recommendations inferred from both papers included in this volume and the discussion arisen during the workshop and synthesized by the sessions chairmen/rapporteur are presented.

End points

Session 1: Water Management. *Chairman*: *Goetz M. Richter (Rothamsted Research, UK)*

Global climatic and economic changes are occurring rapidly and could force us to pose and answer the following questions:

- Are we preparing ourselves for future water shortage and less well distributed water resources in the Mediterranean basin and are we *good stewards of the environment by* using water and soils more *efficiently and sustainably*?
- Do we *pay an honest price when* water is exported from arid areas to humid areas (fruit, vegetable, flowers) and do we *share justly* the wealth of water when it crosses boundaries between nations?

The key messages of the different presentations will and proposed future research will be scrutinised according to these key criteria.

The views on water management were presented at various scales, from regional to national and to field/plot scale perspectives. Talks focussed on engineering, agronomic and economic control tools, and several case studies from Tunisia, Morocco, Lebanon, Turkey and Italy emphasised the economy-drivers of productivity (subsidies, fees). Specific plant physiological and soil quality problems highlighted the system sustainability.

Water resource optimisation: the overall efficiency of water use in agriculture is still below 50% due to losses during distribution and inappropriate allocation within the network (Caliandro *et al.*). In this presentation it was also highlighted how the actual water demand of each crop is often unknown and that excess application to assure profitability is the basis of decisions. Pricing would be a good tool to improve regulation.

Water saving measures were greatly adopted in the southern Mediterranean according to research findings and funding provided by national and international funding agencies (Ben Mechlia). Drip irrigation was implemented, and supplemental irrigation enabled countries to be self-sufficient and to be also food exporters. - Demand for irrigation is still increasing and exceeding ecological balance, displacing locally more appropriate dryland agriculture, and exerting pressure on ground water resources from unregulated private wells.

Sustainable agricultural production (Karam & Geagea) can only be achieved by developing and implementing management practices through (a) integrated technical and scientific research and (b) giving water the real value in terms of product, environment and livelihood of the society. For Lebanon it is essential (1) to integrate indicators of on-farm management and performance to indicators at the scheme and regional level, and (2) establish best management practices to increase WUE. Despite great scientific advances (deficit irrigation) water losses are high during distribution and savings are costly. - Methods applied: FAO24 method, empirical crop response function, use of local site specific indicator plants to sense water stress.

The situation in Morocco is characterised by large regional and annual variability of water availability, 30% of the agricultural land receiving more than 400 mm per year. The approach to improve WUE is based on agro-ecological topographical and integrated soil-water management implementing conservation agriculture and supplemental irrigation (1 Mio. ha). 83% is still managed as surface irrigation and anticipated reduction in water availability and increasing demand (climate change) makes it necessary to restructure the agricultural sector, which is based on small holders (70% < 5 ha). Illiteracy hampers all envisaged changes. As water scarcity is likely due to higher demands from producers and climate while supplies reduce one needs creating a specific framework for research and development in the field of the sustainable use of water resources in agriculture, which emphasizes technical, social, economic and policy aspects.

Short presentations gave information about specific research topics:

- Ozone can reduce grain yield by 48 %, simultaneous water stress protects against ozone damage (Bou-Jaoudé)
- WUE in olive production (fresh weight per unit rain + irrigation) is not a useful indicator for farming income; less water will produce lower yield despite similar WUE; one can increase farming income by intercropping (Masmoudi).
- Problems of intensifying oasis system were presented: lack of research in palms, difficulty to measure ET from tree and soil; different types of plantations with wide range of irrigation; salinization can be a problem (Mekki)
- A generic and flexible model system was presented in Unified Modelling Language (UML) which can be adjusted to variable degree of detail and complexity (Trevisiol)
- Most important parameter of water use in Turkey is the expression of economic value (Euro/water unit), which varies across the 24 water districts in Turkey; management is based on participatory scheme, imposing realistic fees and effective subsidy policies.

Session 2: The efficiencies (small scale). *Chairman: Jordi Araus (CIMMYT, Spain)*

This session was focused on the water efficiency, covering from a wide perspective different ways and scales on how water use efficiency in Mediterranean agriculture may be improved: it comprised three main lectures (from Profs. T.C. Hsiao, University of Davis, USA, J. Bort, University of Barcelona, Spain, and R. Tuberosa, University of Bologna, Italy), which somehow covered in a harmonious manner the whole range of approaches and disciplines (from the gene level to the regional scale) around water use efficiency.

First lecture, from Prof. Hsiao, and entitled "*Suggested Approach for Improving Water Use Efficiency*", was very wide in nature and therefore fully appropriate to open the session. He displayed in a very logic and pedagogical framework the different ways water use efficiency may be improved. After an introduction dealing with the finite nature of water as a resource and the fact that demand and competition for water is increasing, he raised the question if can we increase agricultural production to meet demand while facing decreasing water supply, considering that plant growth is closely linked to water use and that basic "Water Productivity", the ratio of biomass produced per unit of water transpired, is nearly constant because CO_2 assimilation and transpiration share many aspects (e.g. the gas diffusion route) in common. But still there are already available opportunities for improving CO_2 assimilation, including crop management (e.g. nitrogen nutrition, cultivation timing). Other avenues through biotechnology and genomics may perhaps become a reality in the long term (e.g. to introduce C_4 or CAM metabolism in C_3 crops, better osmotic adjustment and root system, stay green), providing better knowledge is acquired on complex and multigenic traits and the trade-offs of introducing such traits are affordable. In such a point Prof. Hsiao raised his concern on the need to balance resource allocation between biotechnology and numerous other means to improve water productivity. In fact he claimed that too much emphasis has been devoted not just to the biotechnological (not yet realized) but even to the physiological (or biological) approaches to improve water productivity (which produce only minor improvements), while forgetting other approaches. In fact a number of means exist to increase basic water productivity of plants, no related with the biology of the plant itself (that is with the "basic water productivity). In this context Prof. Hsiao propose to take a multi-prone approach, going beyond basic (or biologic) water productivity, as the most effective way to improve overall water productivity of the crop. This approach is based in to divide up water productivity process into sequential steps ("chain of efficiency steps" - from: water from reservoir to root zone). It is based in a couple of simple and logic considerations: small increases in several productivity (i.e. efficiency) steps make a large increase in overall water productivity, and the more steps improved, the larger is the overall improvement.

Last part of Prof. Hsiao presentation covered a quite different scenario: dryland agrosystems, which are very common for animal production in many regions of the world, including the Mediterranean, where overgrazing reduces water use efficiency drastically. In fact these degraded rangelands offer the greatest potential for improving water productivity, but it can only come about when supported by changes in political, social and economical policies.

Next two lectures concentrated in cereals, which are, for area cultivated and importance as a staple, the main crops in the South and East of the Mediterranean basin. First one, "*Water Use Efficiency (WUE): the case study of C_3 cereals*" was developed by Prof. Bort. This presentation focused on the physiological attributes that determine water use efficiency in WUE in cereals and ways to improve it. Before entering fully in the matter Prof. Bort explained the several scales, definitions and terminology of water use efficiency (from leaf to crop level and from instantaneous, based on gas exchange measurements, to agronomic water use efficiency). This part was very appropriate considering the multiplicity of nomenclatures used by different authors (a good example is this session where the terms water productivity and water use efficiency were used somehow in indistinct way in different lectures). Further he introduced the basics of carbon isotope discrimination as an integrative indicator of water use efficiency, because its implications for drought breeding and the large amount of literature on the subject available for cereals. Using carbon isotope discrimination as a proxy for water use efficiency Prof. Bort highlighted the dilemma of breeding for high or for low water use efficiency. Breeding for low intrinsic water use efficiency (and thus high discrimination) seems to be the best strategy under moderate drought to good (e.g. fully irrigated) environments, when rainfall are expected during the crop cycle, whereas the reverse (low discrimination) stands for drought prone conditions, particularly when crop growth relies only on the water stored prior planting. Otherwise breeding for high intrinsic water use efficiency, if achieved only through a limitation in stomatal conductance, may represent a penalty for final yield. Another topic tackled was the importance of the ear, frequently neglected as a main photosynthetic organ contributing to filling of grains. Intrinsic water use efficiency of the ear is higher than that of the flag leaf and there is genotypic variability, which made this trait a candidate for phenotypic evaluation in breeding programs aimed to improve water use efficiency.

Third lecture, entitled "*Genomics approaches to enhance water-use efficiency and drought tolerance in cereals*" was presented by Prof. Tuberosa and his team from the Dept. of Agro-environmental Sciences and Technology, University of Bologna. Most of the presentation of Prof. Tuberosa concerned on how to link precision phenotyping with a proper genotyping in order to assess gene function and therefore to foster cereal breeding for drought. Nevertheless he started with a broader scheme emphasizing the basic concepts and potential different applications of genomics in the field of plant breeding: either to isolate and manipulate single genes, to move genes across species (genetic modified crops), gene expression across entire genome, dissect the genetic code of an organism, selection based on molecular profile (i.e. marker assisted selection) or to dissect genetic control of quantitative traits, like yield or drought adaptation. In such a sense Prof. Tuberosa, even when deeply involved in genomics and marker assisted selection, clearly stated that so far to present marker assisted selection has not yet used successfully in practical breeding for drought adaptation. In fact among the few questions raised by the audience was the concern on the lack of practical outputs of genomics for improving drought adaptation. Further Prof. Tuberosa presented an interesting example with Maize on how to cloning QTLs for adaptation to drought avoidance, including precision phenotyping on root architecture and field testing. This example illustrated the complexity of the mechanisms involved and the risk to assume a priory statement. Thus, genotypes exhibiting lack of sensibility to ABA yielded more even under the water stress conditions evaluated.

The overall argument of Prof. Tuberosa's lecture went around the need to adopt a multidisciplinary approach for crop improvement. As a prove of concept of this breeding approach, Prof. Tuberosa presented the structure, organization a main achievements of IDuWUE (Improving durum wheat for water use efficiency and yield stability through physicological and molecular approaches). This is an ongoing project for international research cooperation, coordinated by Prof. Tuberosa and sponsored (contract number ICA3-CT-2002-10028) by the Directorate-General for Research, European Commission. Funding Source: Directorate General of Research, European Commission. Prof. Tuberosa concluded with a remark, which illustrates his wide perspective of the problem and perfectly summarize his presentation: "Phenotyping is king… …and heritability is queen!"

Session 3: The efficiencies (large scale). *Chairman: Sayed N. Azam-Ali (Nottingham University, UK)*

This session contained six papers (from G. Rana, CRA-ISA, Bari, Italy; G. Richter, Rothamsted Research Centre, UK; R. Casa, Tuscia University, Viterbo, Italy; R. Albrizio, CIHEAM-IAMB, Bari, Italy; M. Acutis, University of Milano, Italy; N. Lamaddalena, CIHEAM.IAMB, Bari, Italy) that considered the efficiencies of evapotranspiration at both the canopy and the regional scales in terms of biotic factors (ordinate) and abiotic factors (abscissa) in the dry matter/evapotranspiration relation. The first two of these presentations identified the influence of plant and environmental factors on calculations of efficiency. The remaining presentations considered environmental influences and management options to optimise production efficiencies, mainly of the transpirational component. Biotic factors influencing the ordinate included: the energy equivalent of carbon in terms of plant compounds, the energy costs of N fixation and the contribution of roots. Abiotic factors influencing the abscissa included separation of the surface evaporation and transpiration components and the influence of atmospheric moisture content. There was a timely debate on the normalising influence of atmospheric vapour content on calculations of efficiency. Comparisons between the use of mean atmospheric saturation deficit (D) and potential evaporation (ET_o) were provided with clear evidence that a) any measures of atmospheric humidity differences between sites and seasons account for apparent differences in transpiration efficiency and b) from comparative datasets at the same location, ET_o provided a more reliable and consistent normalisation of calculated efficiency than D alone. This provides common estimates of transpiration efficiency within various commodity groups and especially between C_3 and C_4 species.

A number of management interventions on maximising the transpirational component of evaporation were considered. These included, the use of conservation tillage and soil topography (e.g. through tied ridges) to minimise the soil evaporation component, and the management of canopy surface area (leaf area index, fractional interception and ground cover) and canopy architecture to maximise the transpirational component. The use of evaporation calculations and concepts were considered in the design of simple but robust methods for irrigation scheduling using microcomputers.

Future research needed

1. Improving type of distribution systems and timing of irrigation adjusted to the needs of crops using intelligent systems based on (controlled) water stress and demand prediction; tertiary treated municipal waste water needs being included.
2. Study sustainability and implement a water basin framework to regulate overall productivity in the Mediterranean for irrigated and rainfed agriculture alike. Integrated approach (ecology and economy of water/nutrients/salt) to develop indicators for WUE and the whole hydrological cycle applying models at different scales, considering the real costs and sustainability.
3. Improve water use efficiency based on water consumption by the crop using modern irrigation methods which result in reduced water losses; more experiments are needed with respect to different agro-climatic zones.
4. Introduce new modelling tools and information technologies (e.g., GIS, crop growth models, water distribution models), develop drought resistant crops (e.g. fruit trees). Instate research and knowledge transfer in rural areas, improve capacity building for regional cooperation, and develop participatory systems.
5. Overall, it was accepted that global change and increasing human demands would make water more valuable and that we need
   - Improve estimates for the actual demand, regional estimates and evaluation of crop coefficients to allow precise quantification in space and time.
   - Consider whole system with all (alternative) products with different types of irrigation (rainfed, deficit irrigation, supplemental irrigation, partial root drying) and the resources available.
   - Install a participatory system based on fees, which reflect the real value of water and the profit of the respective product.
6. It is needed to adopt a multidisciplinary approach for crop improvement, combining the expertise of breeders, biotechnologists and molecular biologists, physiologists and bioinformatics.
7. Genomics-assisted breeding, which imply to move from QTLs to genes.
8. Surface Evaporation
   - There remains considerable scope to manipulate and reduce the surface evaporation component of evaporation through management interventions.
   - More than twenty years after its introduction, there appears to be no practical advance on the Ritchie (1983) equation. Serious attention should be given to:
     - experimental and
     - theoretical methods of estimating surface evaporation from vegetation with incomplete and complete cover and different architecture.
9. Transpiration Efficiency
   - The normalising, unifying influence of atmospheric demand provides a strong incentive for:
     - appropriate management practices that optimise crop growth against the seasonal variation in atmospheric demand
     - better theoretical and experimental methods of calculating and measuring the atmospheric demand throughout the growing season.
   - Correction for ET_o allows the grouping of different species onto a common efficiency. This provides management and experimental incentives to focus on:
     - increasing the abscissa i.e. transpirational fraction to maximise biomass and/or
     - the characteristics of the biomass in terms of nutritional, commercial or communal value.

10. It is necessary to develop correct and, above all, univocal definition of water productivity (WP) and water use efficiency (WUE) and to study the links between them. Possible definition to take into account could be:
    - Biomass/actual evapotranspiration (ET)
    - Yield/ET
    - Incomes /used water by the crop (WU)
    - Value/ET
    - Yield/ irrigation (IWU)
    - Value/IWU
11. Methods and models are necessary to up-scale the WUE and the WP from field to
    - Farm
    - Institutional scale
    - Sub-national scale
    - Country

Discussion it is necessary for defining the Reference point (i.e. potential production….). Possible indicators to be analysed in detail for the Mediterranean region should be

Farm level
- Total yield / total water (crop systems including fallow or set-aside, and rain-fed crops)

Association of farmers (water users associations) level
- Water volume in the dams (or reservoirs) / served area
- *Irrigated surfaces (in ha) / volume of allocated water*

Ecosystem (with water having a multifunctional role) level
- Aggregated WUE (benefit / water used)
  (using remote sensing + models)

12. Research is necessary to individuate indexes, as a composite of more than one indicator, for a more complex evaluation of WP and WUE in the Mediterranean region.