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Fereres E.

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E. Fereres
Instituto de Agricultura Sostenible-CSIC and Universidad de Córdoba,
Apartado 4084, 14080 Córdoba, Spain

SUMMARY – Through this presentation the importance of the sustainability of the agricultural systems in the Mediterranean area is stated. The potential of several technologies are analyzed. The achievements and opportunities of biotechnology and other technologies such as conservation tillage to improve the sustainability in this area are commented. New tools such as geographic information systems (GIS) and the use of crop simulation models are discussed for the characterization and assessment of improved agronomic technology and the sustainability of the agricultural systems.

Key words: Mediterranean, rainfed agriculture, systems, biotechnologies, GIS, crop simulation models.

RÉSUMÉ – *"Augmenter la durabilité des systèmes méditerranéens d'agriculture pluviale". Cette présentation met en relief l'importance de la durabilité des systèmes agricoles dans la région méditerranéenne. Le potentiel de plusieurs technologies est analysé. Il y est commenté les acquis et les opportunités de la biotechnologie ainsi que d'autres techniques telles que le labour de conservation pour améliorer la durabilité dans ces zones. De nouveaux instruments tels que les systèmes d'information géographique (SIG) et les modèles de simulation des cultures sont discutés dans le but de caractériser et d'évaluer une technologie agronomique améliorée pour la durabilité des systèmes agricoles.*

Mots-clés : *Méditerranée, agriculture pluviale, systèmes, biotechnologies, SIG, modèles de simulation des cultures.*

Towards more sustainable agricultural systems

The objective of this presentation is to describe the challenges that Mediterranean rainfed agricultural systems (MRAS) are facing now and in the immediate future and to express my views about the potential contribution of various science and technology options for their sustainability.

It is instructive to first define what is meant here by sustainability. This concept as it applies to agriculture, was defined by the Technical Advisory Committee (TAC) of the Consultative Group in International Agricultural Research (CGIAR) in 1988, one year later after the idea of sustainable development was publicized. TAC defined sustainable agriculture in the following way: "sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources".

Fifteen years later, following a shift in focus in the research conducted in the centers of the CGIAR towards the poor, a new definition for sustainable systems developed by TAC focused on: "preventing future poverty and food insecurity by developing technologies that can help avoid future degradation of the natural resource base on which food, fiber, fuel and fodder production for the poor depends".

It is my view that the sustainability concept as it applies to agriculture should be assessed only in relative terms; that is whether one system is more sustainable than another, or whether adopting a certain measure will make the system more or less sustainable. The factors that make this concept relative are, first, the time scale considered and second, the rate and degree of change of the agricultural system in question. It is obvious that, depending on the time scale considered, a system may or may not perpetuate itself. It is also evident that ecosystems undergo continuous change and agroecosystems are no exception. These changes can alter the system direction and make it more or less sustainable. Thus, agricultural managers must steer these systems towards a moving target and this is why a continuous supply of science and technology is needed to provide them with new instruments that will make these systems more sustainable.

In MRAS, it is easier to find examples where agricultural systems have persisted successfully for an indefinite period, than to find cases of systems that have proven to be unsustainable. This is probably because new systems soon become fragile under the severe population, environmental and cultural pressures of the region and end up failing in a short time. The truth is that, despite emphasis on diversity, there are only a few successful MRAS that have been around for a long time. At present, MRAS are dominated either by winter cereals or by a tree crop, normally the olive. Barley takes over wheat in the low precipitation areas while, in some countries the olive dominates marginal soil areas, provided that low winter temperatures do not represent a serious threat to olive production. There are very good reasons for the reduced diversity of cropping systems in MRAS and attempts to introduce or re-introduce alternative crops have had limited success so far. Risk aversion is a pivotal feature of agriculturalists and is the major justification for the success of the major crops mentioned and for the limited diversity found at present. Whether increased diversity would contribute to increased sustainability is a subject that deserves serious research efforts.

What are the challenges faced by MRAS? They are all centered on the concept of producing sufficient food that is safe and of high quality in agricultural systems that may be considered sustainable. Thus, food security, food quality and sustainability are the primary objectives of improved management of MRAS. To meet these challenges, more science and technology is urgently needed, despite the widespread reduction in public funding for scientific advancement in agriculture that is occurring today. Progress is to be expected from new applications to agriculture of the advances in molecular biology (biotechnology) and in information and communication technologies (ICT). Following are some ideas on how such advances may benefit the sustainability of MRAS in the future.

Biotechnologies: Achievements and opportunities

Plant breeders have been genetically modifying crop plants since long ago, but the term genetic modification has taken another meaning for the general public in recent years, as the advances in molecular genetics have allowed the genetic transformation of organisms by the introduction of foreign genes from other species.

Biotechnology has introduced remarkable change in plant breeding methodologies and has changed the approaches to crop protection in a few important crops. The area planted to biotech crops has increased from 1.7 Mha in 1996 to 52.6 Mha in 2001. However, 77% of the 52.6 Mha are devoted to herbicide-tolerant soybean and most of the rest to insect-resistant corn and cotton. These advances have two major features: they are the product of single gene modification and have been mostly produced by the private sector for markets large enough to justify the investments in the new technology.

Can the recent success of crop biotechnology be extended for the improvement of MRAS? So far, those using biotech crops are located in systems of high productivity and/or of high pest pressures, conditions required to justify the additional expense of the improved seeds. Modern plant breeding has already produced crops of high yield potential that is seldom realized on MRAS because of the water limitation. Would then biotechnology be able to dramatically increase the potential yield of water-limited agriculture in MRAS? Personally, I am skeptical that this can be done in the short (5-10) or medium term (10-20 years). Yield under drought is a complex trait, even more complex than yield potential, and it is unlikely to be modified by the expression of a single gene. Drought patterns vary from location to location and from year to year. Thus, as drought patterns change, a favorable feature in a genotype may not represent any advantage for the improved cultivar or may even be disadvantageous.

There are very few examples of physiologically based breeding programs that have been successful in producing improved varieties for MRAS. One recent example illustrates the difficulties. In the early 80s, it was found by Farquhar and Richards that discrimination in the uptake of the ^{13}C isotope was correlated with water use efficiency. It has taken a long-term commitment of public research in Australia (over 20 years) to produce an improved cultivar based on selecting for ^{13}C

discrimination. Furthermore, such cultivar offers only a modest yield advantage over commercial cultivars, about 10% maximum for yield environments of 1t/ha.

For molecular biology, which is further apart from the expression of crop yield than crop physiology, the difficulties for improving yield by single gene manipulation can only be greater. Additionally, the spatial and temporal diversity in environments in MRAS, reduce the commercial potential of improved varieties, and thus the interest of the private sector in investing to meet this challenge. At present, biotechnologists have captured the attention of the science bureaucrats and are attracting much public funding, but their success will be short lived if they persist to work in isolation from other agricultural scientists. If biotechnology is to have an impact on the development of new cultivars for MRAS in the future, improvement programs should be based on the following requisites: (i) improved knowledge of the mechanisms determining crop yield; (ii) demonstrated benefits of specific traits at the field scale; (iii) long-term investments by the public sector; and (iv) multidisciplinary teams to orient correctly the crop improvement efforts. It is unfortunate that improvement programs of such nature and of sufficient dimension have not been launched so far in the Mediterranean Basin.

Improving management for increased sustainability of MRAS

If the short-term prospects of dramatic yield increases in MRAS via biotechnology are dim, what can be done to increase their sustainability? For most farming systems, the gap between the yield levels that may be attained within their environmental constraints and those actually achieved, is substantial and is not closing in many areas. In addition to the yield gap, the conservation of natural resources, namely soil and water, is critical to make MRAS more sustainable. Contrary to biotechnology and genetic improvement where the private sector is an increasingly important partner, resource conservation belongs almost exclusively to the public domain and even individual farmers do not get sufficiently involved in this goal. Both the yield gap and resource conservation are largely management dependent, and this is why improving management should be the objective of highest priority in achieving more sustainable systems in Mediterranean rainfed agriculture.

New tools for improving the management of natural resources

Managing resources for higher yields and for conservation may profit now from a range of technologies derived from ICTs and applied to scaling up field observations, to the farm, the watershed, and the region. Without the capabilities of scaling up point observations for assessing the behavior of the larger units, it would be impossible to predict whether a system is becoming more or less sustainable. The various technologies may be grouped into two broad areas: those used for spatial analyses and integration and those used for simulation and forecasting. Geographic information systems and geostatistics are now used to develop spatial analysis of various kinds and applications. Global positioning systems in combination with agricultural equipment capable of applying variable rates of agrochemicals within the field form the basis of an improved management technology labeled precision farming. Precision farming is suited to the management of large fields that, in the search for lower production costs, were previously managed as units often causing environmental damage. Precision farming will definitely contribute to the sustainability of farming systems characterized by capital intensive, large farming units. However, excessive use of agrochemicals is not of primary importance in the small farms of MRAS.

One of the tools with more potential for the assessment of sustainability are the simulation models. Simulation models, when validated with appropriate, long-term experimental data, constitute the most powerful instrument to predict the behavior of agricultural systems. Weather simulators offer the possibility of developing alternative scenarios that are then evaluated with model predictions. The range of applications of simulation models is enormous and their potential in evaluating the sustainability of MRAS is very high. They may be used in scenario assessment, ideotype design, or for real time management, among the many applications. The primary limitation for advancement is the very scarce investment in research on this important area, as is now common in most fields of agricultural sciences.

One of the collateral benefits of the increased investment on research in climate change, are the improvements in mid-range weather forecasting in many world areas. The use of the ENSO (El Niño/Southern Oscillation) in Australia is one successful example that hopefully will be extended to other areas, including MRAS areas. Improved accuracy of weather forecasting leads to response farming strategies, in which planting dates, input levels, etc. are adjusted every season for reduced risks and higher farm profits.

The techniques discussed above are just a sample of the tools available for improving the management of MRAS. Needless to say that there are many other agronomic strategies and tactics that may be used to optimize the use of water, the limiting factor "*par excellence*" in MRAS. Manipulations of the environment by appropriate management practices, (i.e., conservation tillage) directs a large proportion of the seasonal rainfall towards transpiration (T). The conversion of T into biomass and economic yield is also environment and management dependent, and crop manipulations via maturity length, planting date, etc. are crucial in optimizing the use of water in MRAS. The ample opportunities that all these techniques offer for improving sustainability in MRAS are hardly explored in many of these systems.

Conclusion

Excessive emphasis on the biological component of farming systems, i.e., the seed, has not benefited the development of appropriate management and conservation techniques, which are essential for the improvement of sustainability. Additionally, investments in technology transfer and in agricultural extension for the dissemination of such useful concepts and tools have clearly diminished in recent years. Without a turn around in this trend, the search for increasing sustainability in MRAS will be futile. If society is really concerned about the sustainability of its agricultural systems, scientists must devote time to formulating the correct messages and to promoting them, so that this important issue attracts the public’s attention.