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# Sustainability in Dryland Farming Systems

*Elias Fereres*

## Introduction

Dryland farming systems are very fragile because of their dependence on an uncertain water supply. Traditionally, dryland farmers have attempted to exploit the natural resources with a very conservative attitude to avoid crop failures and the consequent famine. Such avoidance of catastrophic events has had a major influence in the planning and management of dryland areas. Past experience has dictated that, given the uncertainty in rainfall, it may be better to leave resources untapped than to risk the consequences of an exhaustion of the water supply before the crops have completed their life cycles. Practices such as leaving land to fallow, low nitrogen fertilisation levels, low density plantings of annual and tree crops and the use of short-season cultivars, have all been developed to reduce yield fluctuations and to ensure that a minimum yield is always harvested regardless of drought severity.

An agriculture may be considered sustainable when the current practices do not threaten the future exploitation of the natural resource base. The concept of sustainability as it applies to agricultural systems has been implicit in many dryland systems; for instance, the cereal-fallow system practised in the Mediterranean basin since long ago is an example of a system that may be considered sustainable. Another example is the oak-pasture sylvopastoral system of Western Spain and Eastern Portugal which has been around for several centuries with very little ,if any, degradation of the natural resource base.

Agricultural systems and management practices evolve, however, and what was considered sustainable in the past may be unsustainable for the future. In the last decades, the population growth in the arid zones has required a concomitant increase in food production which must come at the expense of the increased exploitation of the very limited natural resources available in those environments. The challenge of increasing crop productivity while conserving the resources and, at the same time, maintain economic viability, is at the heart of the changes that agriculturalists must devise to achieve a sustainable agriculture in the rainfed areas. Following is an overview of the main strategies and tactics to be applied to dryland Mediterranean systems with the above objectives in mind.

## Dryland Cropping Systems in the Mediterranean

Farmers in the semi-arid zones have normally very few options in terms of crop choice. The situation in the Mediterranean is somewhat exceptional in that a fair number of options are available with both perennial and annual crop species alone or in association (Table 1). Of particular interest are some of the woody species such as olive or almond, which cover vast areas in the Basin.

Many marginal areas in terms of steep slopes and/or shallow soils are planted primarily to olives and also to almond trees. In Spain alone there are over 2 million hectares of olive groves, many on very fragile soils. Current soil management practices of conventional tillage are of concern because of the erosion risks, which threaten the sustainability of the system. The obvious solution of using a cover crop to prevent erosion has not been adopted by farmers because of the competition for water between the cover crop and the tree. Currently, the high market prices for olive oil have encouraged additional plantings in areas even less suited to sustainable olive production.

Winter cereals continue to be the primary crops grown in the Mediterranean Features that determine their dominance include their drought tolerance and their developmental patterns which adapts very well to the seasonal rainfall patterns. International breeding programmes have produced high yielding varieties which have adapted well to dryland cropping, particularly in areas of intermediate to high rainfall. In the marginal rainfall areas (below 250-300 mm) the impact of such varieties has been negligible and there is evidence that the local landraces perform as well or even better than the imported varieties. The research programme of ICARDA is contributing to the development of locally adapted cultivars in the low rainfall regions but it has obvious limits in terms of productivity when the total annual rainfall is so low. Nevertheless, productive cereal cultivars in those areas can offer the only cropping option, as pastures or shrubs are the common vegetation cover devoted to extensive sheep or goat husbandry.

Continuous cereal cropping can cause long-term problems associated with soil-borne diseases. In those cases, either the use of fallow or the rotation with other crops will increase the sustainability of the system. Grain legumes have been the preferred crop choices for inclusion in the rotations but they have not succeeded as viable alternatives to the winter cereals for several reasons. Most grain legumes are highly susceptible to diseases and to parasites such as broomrape. Grain legume yields are unstable than those of cereals because they are more susceptible to drought. Yield instability of grain legumes has reduced their role in the rotations of the Mediterranean to a small fraction of the area, but there are examples of success in growing grain legumes in similar climates such as the lupins in Western Australia. Fallow was practised since Roman times as an insurance against dry years. Both water and nitrogen are conserved when fallowing but the fraction of the rainfall conserved is fairly small and fertiliser can replace the mineralised nitrogen. In recent decades, the cereal-fallow rotation has been largely substituted by the continuous cereal or the cereal-legume/sunflower rotation in most areas of over 350 mm annual rainfalls. Such changes have resulted in higher productivity per unit land area and in greater net returns. The role of fallow in the low rainfall areas is still debatable, but there are new elements to be considered such as the increased erosion risks when the land is left bare. An alternative to fallow in these areas would be the use of perennial pastures or shrubs. It is unfortunate that very little long-term experimentation has been carried out on this subject in the agricultural systems of the Mediterranean Basin.

In summary, there is quite a bit of diversity in the cropping systems of the Mediterranean. In most countries of the Northern Rim, the Common Agricultural Policy of the European Union provides sufficient subsidies to make current systems economically viable at present, but offers very little incentives to increases in productivity or to the protection of natural resources. The situation in the Southern Rim is much more critical as the population pressure demands increases in productivity that cannot be achieved without technological and socio-cultural modifications of those societies. In most systems, however, there are ample opportunities for improving productivity while enhancing sustainability.

## Towards a More Sustainable Agriculture in Dryland Systems

Dryland agriculture is water-limited; thus, improvements must come about primarily by improving the efficiency of water use. Such an improvement may occur at any of the three steps that convert a unit rainfall into a unit of economic yield and which are shown on Table 2. How can we achieve that a high proportion of the rainfall is directed into transpiration? It turns out that many of the measures devised to protect the soil from erosion also contribute to increases in rainfall efficiency. One major improvement, long due, is the use of conservation tillage practices both in annual and perennial crops. Direct drilling of cereals leaving crop residues on the soil surface reduces runoff drastically by increasing detention time and the soil infiltration rate. The shift to conservation tillage practices requires modification of the planting machinery and changes in weed control and in the fertilisation practices. One constraint in some systems is that the use of the straw for animal feed competes with the soil conservation measures.

In the olive and almond plantations, the adoption of conservation tillage is even more urgent than in annual crops as the lands devoted to such tree crops have generally a higher erosion risks. Unfortunately, developments in conservation tillage for such crops have lagged behind those in annual crops, and there is not a universal solution to the problems that conventional tillage cause in olive groves. No-till systems with herbicides have been used but, in many soils, the infiltration rate declines with time and that could lead to even more severe erosion than with conventional tillage. Cover crops have the problem of competition for water, but if planted in strips and killed after the winter rains before they can extract the water that may be use later by the trees, do represent a viable alternative. Such cover crop plantings will definitely require economic incentives for their adoption. It appears that, given the many subsidies currently available to agriculture, a fraction could be devoted to fund the use of cover crops in steep orchards with substantial reductions in soil erosion and, consequently, with increases in the sustainability of those systems. Current tillage practices in the tree crops of the Mediterranean represent a threat to resource conservation. Tillage should be minimised and, where possible, cover crops should be encouraged.

Reducing evaporation losses so that more water is used in transpiration can be achieved by agronomic measures, which include early plantings, high sowing densities and adequate fertilisation (Cooper et al., 1987). Early plantings combined with cultivars that have high initial growth rates provide the best combination to cover the soil early with vegetation and therefore, reduce the evaporation losses from the soil to a minimum during the rainy period.

Ensuring that the maximum plant biomass is produced per unit water transpired (step 2, Table 2) requires that crops are grown at times of low evaporative demand or that a major portion of their life cycles occur during those times. In that respect, winter cereals have an advantage as they avoid the hot summer period. On the other hand, evergreen trees, such as the olive, are always intercepting radiation, including those winter and spring days of highest water use efficiency. In a winter day, even a sparse olive tree canopy intercepts a substantial proportion of the incoming radiation because of the low solar angle. The mild temperatures and the low vapor pressure deficits determine a high ratio between carbon gained and transpirational loss. Even though leaf photosynthesis in olive is relatively low, the yield of a typical olive grove, expressed in terms of glucose-equivalents, is greater than what can be obtained from any alternative annual crop in the same soil-environment combination.

Finally, the available water supply and the crop water demand must be matched to avoid severe water stress that can specifically decrease the fraction of harvestable biomass (step 3, Table 2). Such fraction, called harvest index, is maximum under ample water supply but is reduced by the severe stress that develops if the crop has not completed its life cycle before the available water is exhausted. Harvest index of winter cereals approach 0.5 under ideal conditions but seldom exceed 0.3 in dryland systems. Thus, there are opportunities in increasing HI by avoiding crop water deficits and by using the appropriate varieties to match the water available.

The measures suggested above require a greater degree of control and a higher level of knowledge of the system that farmers have in the dryland areas. The strategic or long-term decisions must be based on the quantitative assessment of the climatic features of the environment while the tactical (short-term) decisions require advanced knowledge of the expected weather, of the soil fertility levels, and of the yield potential of the cultivars to be grown (Loomis and Connor, 1992). One development that could be of great help to dryland farmers is the improved accuracy of rainfall prediction. An indication of the type of season to be expected (even to know if it would be wetter or drier than normal) could minimise risks, improve input efficiency such as amount and timing of fertiliser application, and reduce environmental degradation. In some areas of Australia and elsewhere there are good prospects for long-term rainfall prediction.

As new management strategies are developed to make agricultural systems more sustainable, a critical question arises: How can we evaluate the effects of current practices on future performance? Or, can we predict the impact of a newly proposed technique on the sustainability of the system? There are essentially two ways to answer such a question. One is by the evaluation of long-term experiments (over 10 years) and of the successful experience that may exists in a farm or a region. The other is by conducting an analysis of the system using simulation models. A simulation model that mimics the behaviour of the real system, improves the understanding of how the system functions and can predict future behaviour. There are many types of crop simulation models (Sinclair and Seligman, 1996) and they all have important limitations. Nevertheless, they will become an important tool in the future as we attempt to make dryland agricultural systems more sustainable.

## References

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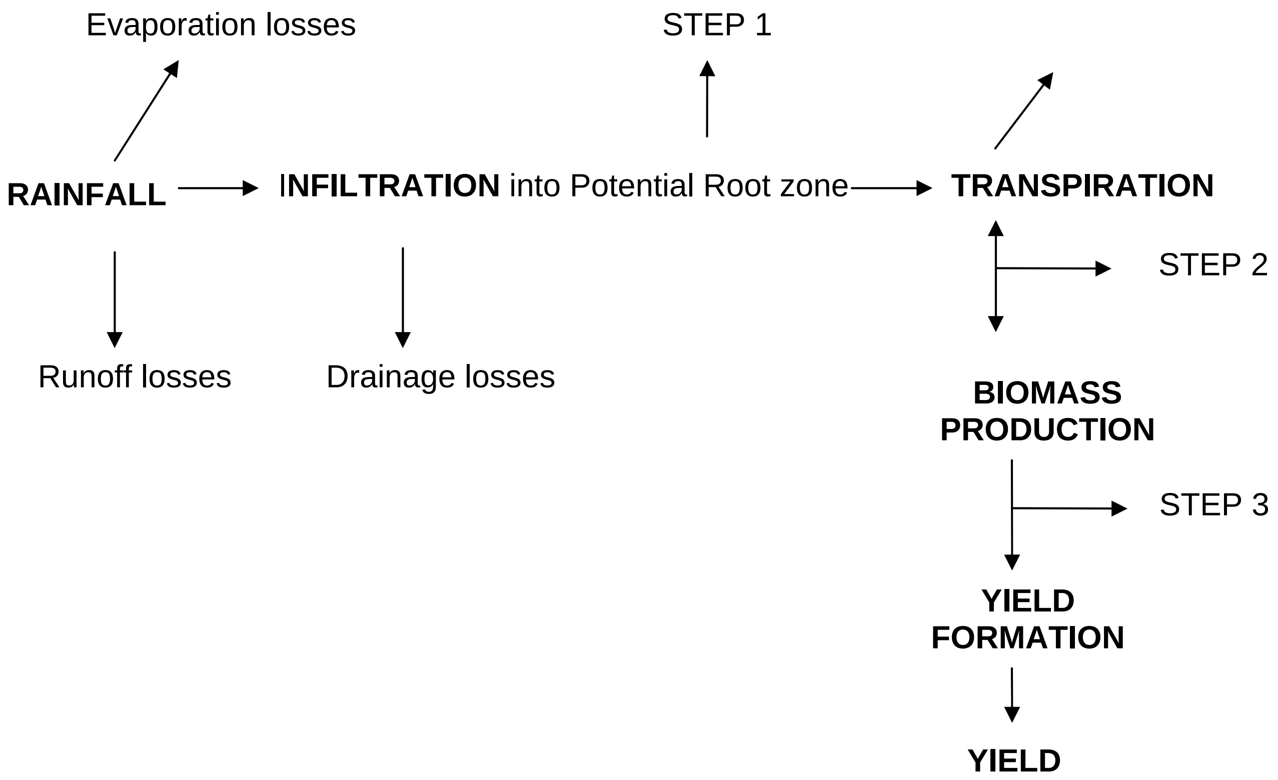
Loomis, R.S. and D.J. Connor (1992): Crop Ecology. Cambridge University Press. 567 p.

Sinclair, T.R. and N. Seligman (1996): Crop modelling: from infancy to maturity. Agronomy Journal:698-703.

## Annexes

| DRYLAND DROPPING SYSTEMS IN THE MEDITERRANEAN | | | |
|---|---|---|---|
| Cropping Systems | | | |
| Annual | | Perennial | |
| Continuos cropping | Fallow | Herbaceous | Woody |
| -Cereals | Water and | Pastures | -Olive |
| -Legumes: | Nutrient | | -Grapes |
| -Grain | conservation | | -Almonds |
| -Forage | for risk | | -Figs |
| -Other | reduction | | -Oaks, etc |
| -Rapeseed | | | |
| -Sunflower | | | |




Steps :
1. Most of the Rainfall goes into Transpiration (Minimun Runoff an Evaporation losses)
2. Maximun Carbon gained per unit water loss in Transpiration
3. Maximun proportion of the biomass converted into economic yield (Harvest Index)