# Review Report on Irrigation Management Scheme

**_ORGANIKO LIFE+ PROJECT_**

*Revamping organic farming and its products in the context of climate change mitigation strategies*

*Type of deliverable: Report*

*Action C1*

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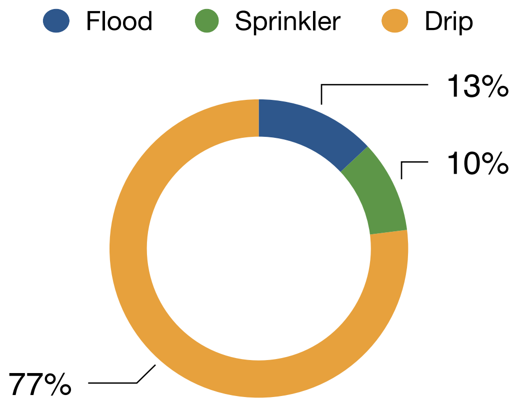
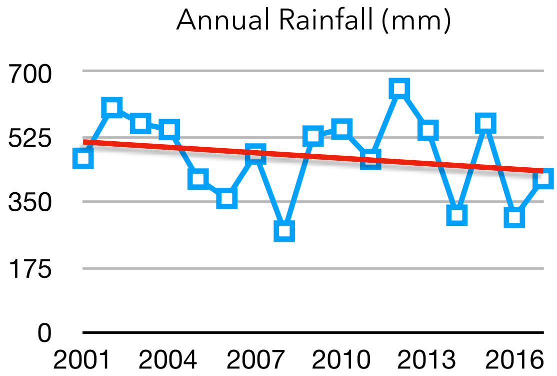
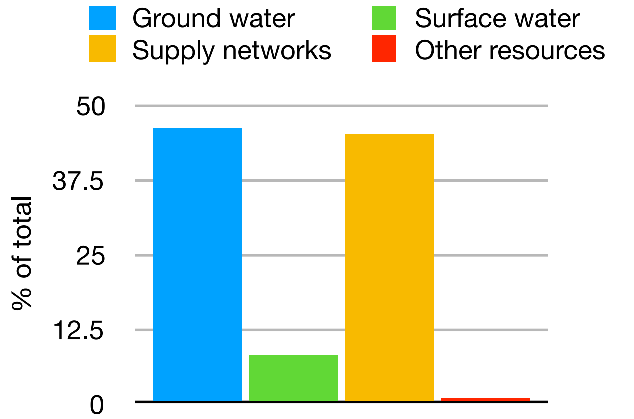
# IRRIGATION FACT SHEET

## IRRIGATION SYSTEMS IN CYPRUS




## IRRIGATION WATER RESOURCES




## Facts for the past 30 years

Mean Temperature increased by 0.5 °C

Mean Precipitation reduced by 9%

- Barley is a rain-fed crop and yields are strongly depended on rainfall
- High efficient irrigation systems are dominant in organic farming apple orchards
- !! There is an emerging need for the development of drought tolerant varieties under the scheme of organic farming
- !! Novel Reduced irrigation methods are available and need to be integrated under local conditions taking into account agronomic and environmental characteristics

# Executive summary

## Σκοπός

Στόχος του παραδοτέου είναι παροχή λεπτομερών πληροφοριών για τις στρατηγικές άρδευσης στην βιολογική καλλιέργεια των μήλων και του κριθαριού στα πλαίσια της δράσης C1. Συγκεκριμένα τα παραδοτέα “Review Report of Irrigation Management Scheme” και “Irrigation Scheme for each crop” συνενώθηκαν για σκοπούς συνοχής..

## Αντίκτυπος

Για την ολοκλήρωση της έκθεσης, πραγματοποιηθήκε ανασκόπηση όλων των διαθέσιμων μεθόδων άρδευσης σήμερα στην Κύπρο και για τα δύο καλλιεργούμενα είδη σύμφωνα με τα διαθέσιμα στοιχεία του Ινστιτούτου Γεωργικών Ερευνών.

## Αποτελέσματα

Η παραγωγή και η ποιότητα των παραγόμενων προϊόντων σε ξηρικές καλλιέργειες όπως το κριθάρι εξαρτάται πλήρως από την ετήσια βροχόπτωση (χρονικά και ποσοτικά). Από την άλλη πλευρά, η παραγωγή βιολογικών μήλων μειώνεται δραματικά χωρίς την χορήση στα δέντρα καλής ποιότητας νερού άρδευσης και για το λόγο αυτό οι πλήστοι παραγωγοί έχουν εγκατεστημένα βελτιωμένα συστήματα άρδευσης. Οι αρδευτικές ανάγκες των καλλιεργείων υπολογίζονται σύμφωνα με τις μεθόδους που προτείνονται από την FAO.

## Συμπεράσματα

Ωστόσο υπάρχουν σημαντικά περιθώρια βελτίωσης της αποδοτικότητας χρήσης του νερού και της διαχείριση άρδευσης των καλλιεργειών. Για παράδειγμα η παρακολούθηση των επιπέδων υγρασίας στα εδάφη για την βελτιστοποίηση του προγραμματισμού για την άρδευση αναμένεται να βελτιώσει περαιτέρω την αποδοτικότητα χρήσης του νερού. Πρακτικές όπως η κάλυψη του εδάφους με οργανικά υλικά, το κλάδευμα, η αφαίρεση καρπών στο κατάλληλο στάδιο, η ενσωμάτωση κομπόστας και η μείωση των εισροών Ν αναμένεται να βελτιστοποιήσουν την αποδοτικότητα χρήσης νερού της καλλιέργειας.

# Executive summary

## Purpose

The aim of the deliverable is to provide detailed information on irrigation strategies in organic cultivation of apples and barley under Action C1. In particular, the "Report of Irrigation Management Scheme" and "Irrigation Scheme for each crop" have been brought together for consistency purposes.

## Outcome

For the completion of the deliverable, we reviewed all available irrigation methods currently available in Cyprus for both cultivated species (apples and barley) the irrigation management schemes and schedules were developed according to the available data from the Agricultural Research Institute.

## Results

Water availability and its quality are amongst the most important factors for sustainable and environmentally friendly agriculture in semi-arid regions. The productivity of rain-fed crops like organic barley relies mainly on annual precipitation while apple orchards cannot produce adequately without irrigation.  In Cyprus, most of the organic apple farmers have already installed improved irrigation systems thereby reducing the amount of water needed for the crop. The irrigation needs of the crop are calculated according the methodology developed and suggested by FAO.

## Conclusion

However, there is ample scope for improving water use and irrigation management in organic apple orchards. For example, the inclusion of soil moisture monitoring systems to optimise the irrigation scheduling it is expected to further improve the water use efficiency of organic apple orchards. Practices like mulching, pruning and fruit removals at a proper growth stage, compost incorporation and reduced N inputs is also expected to improve water use efficiency of the crop.

# Πίνακας Περιεχομένων

# Introduction

Water availability and its quality are amongst the most important factors for sustainable and environmentally friendly agriculture in semi-arid regions. Water as a resource is crucial not only for agriculture but also for the industry as well as other sectors of the economy like tourism. Water is a critical component of human health, and due to the increase in human population and the climate change, it is expected that significant amount of fresh water will be diverted from agriculture to domestic use. By 2050, the water demand of agriculture worldwide is estimated to increase by 19% due to irrigational needs. Currently, almost 40% of the world's food produced in artificially irrigated areas. Thus sustainable water use management in irrigated and rainfed agricultural systems will be vital in meeting future demands for agricultural goods (Dietrich et al., 2013).

In semi-arid regions, rainfall and particular annual precipitation determine crop growth, productivity, and products quality. In Cyprus, the annual rainfall ranges from 400 to 600 mm and the wet period take place during winter and in principle during this period the amount of precipitation is higher than the evapotranspiration. However, climate change already affected Cyprus climatic conditions and their impact on precipitation and temperature are obvious. The mean annual rainfall since 1990 reduced by 9% compared to that of the period between 1960-1989 while a further decrease of 10 to 15% is expected (Meteorological Service of Cyprus, 2017). In Cyprus, irrigation is needed during the dry season, but due to the climate change, irrigation is required more often depending on the microclimate conditions of the interested region.

Cereals production is depended upon rainfall during winter and the challenge for barley despite its drought tolerance, is to overcome the negative effects of extensive and prolonged drought that are resulting in a substantial reduction of seed and hay production. Our survey showed that is extremely important for the farmers to have varieties with increased tolerance to drought. Fruit crops are dependent upon the soil capacity of storing water during the rainfall season and on irrigation of the crop during the summer period. In organic farming the challenge is to implement practices that will increase the water use efficiency in a climate changing environment. Additionally, measures should be adopted to ensure water supply for an economically viable agriculture.

In this review report we present the management irrigation scheme for apples in to cover the demands of the crop during the growing season..

## Estimation of apple trees net irrigation demands

Water management in apple orchards is a key component for the sustainable and viable productivity of the system. This is particularly important for environmental friendly schemes like that of organic farming. A main challenge for organic apple farmers is their need to adopt and implement efficient and improved management practices to reduce the water footprint of the crop and increase the viability of their agricultural activity. Thereby, farmers should know when and how much water must be supplied to the crop. To achieve this task farmers should be aware about the (i) critical growth stages of the crop, (ii) the different irrigation systems and their characteristics in Cyprus, (iii) the irrigation scheduling and (iii) ways of better usage of limited water supply.

## Understanding tree water needs during the growing season

The yield and the quality of apples is the result of environmental inputs, cultural practices and physiological process. Water has a central role in all these procedures and it is important for the farmer to understand the water status of the crop over seasons and in particular to identify the critical growth stages that are related to productivity and quality. In apple trees there are 3 growth stages during which the crop is susceptible to drought and are described below:

***Budburst and flowering***: Flowering in apples occurs either before or after of the vegetative growth depending on the variety and environmental conditions. Adequate soil moisture is needed 3 to 4 weeks after full bloom in apple trees to maximize cell division and to enhance root growth of the trees. This will support normal fruitlet growth.

***Rapid shoot growth:*** During this stage water availability is important but not critical. During this stage, fruit grows slowly while shoot biomass increases rapidly and the bud formation for next year fruit and leaves occurs.

***Fruit fill:*** During this stage rapid fruit growth take place by cell enlargement. In detail fruit cells begin to fill with carbohydrates and water resulting in a rapid increase of fruit size. In Cyprus, this period ranged between 5 to 7 weeks before harvest and it is dependent on apple variety and the cultivation area. Water availability during this growth stage is critical, since any shortage results in a substantial reduction of yields and quality.

During and after harvest, irrigation is substantially reduced and is only necessary in early-harvesting varieties where shoot and root growth still occurs. During this period, nutrients are stored in trees and water availability is a factor, which control nutrient uptake from the crop. Finally, during the dormancy period (leaf fall) irrigation is not needed.

Besides harvest time, the type of rootstock is a critical factor for the irrigation needs of the crop. In Cyprus, the use of dwarf type rootstocks is limited. Only recently, new organic farming orchards are using these rootstocks to increase the yield per cultivated area. Generally, varieties crafted in dwarf rootstocks are developing shallow root system and the orchard is much more dense compare to the traditional orchard schemes leading to increased irrigation needs.

## Irrigation systems in Cyprus

A key component of sustainable water management is to match water availability and water needs in quantity and quality in space and time (Paranychianakis and Chartzoulakis, 2005). Besides, irrigation method has a decisive effect on irrigation scheduling and determines along with environmental parameters, crop characteristics and soil type the frequency of irrigation and the amount of water that should be applied. In Cyprus, due to the prolonged drought periods, farmers are using localized irrigation methods and particularly

a) trickle,

b) drip and

c) micro-sprayers (mini-sprinklers).

Furrow irrigation is not a common irrigation practice in Cyprus due to the high water demand for this method, the low water use efficiency and accuracy, the high on-going management requirement.

The main components of the irrigation systems used in apple orchards in Cyprus are the following

- ✅ Water source (pressurized local water network, pumping station or elevated water storage tank that is located in rural areas)
- ✅ Control head of the system, which includes particle filters, flow meters, pressure regulators and valves. In conventional farming systems, the irrigation system is connected with fertilizer tank and constant feeding methods are also implemented.
- ✅ Water pipeline network, which includes main and secondary water transfer pipelines, manifolds and laterals. In the pipeline network, several types of emitters are installed and in apple orchards, drippers and mini-sprinklers are usually installed.

## Apple orchards irrigation scheduling in Cyprus

In Cyprus potential evapotranspiration of crops is usually estimated from pan evaporation measurements, following the procedure suggested by FAO. The evaporimeter used is the screened USWB Class A Pan, which has been tested more than any other worldwide. The methods using meteorological measurements are usually preferred because they are easier, and meteorological measurements are usually readily available. The estimates obtained by this method, however, express in reality the evaporative demand of the atmosphere.

Particularly, six methods estimating the evaporative demand of the atmosphere were tested under Cyprus conditions in the past. The methods used were the screened USWB Class A Pan evaporimeter, and the formulae of Penman, Turc, Jensen&Haise, Thornthwait, and Blaney and Criddle. The estimates obtained with the above methods were tested against potential evapotranspiration values, determined by the water balance of the soil profile in field plots. Pan evaporation gave the best estimates and has successfully been used in Cyprus to guide irrigation and it has been established as a standard instrument in meteorological stations.

Particularly, crop evapotranspiration (ETc) was calculated directly from pan evaporation (Epan) measurements using a single coefficient, which expresses the ratio of ETc to Epan (Metochis, 1997). Briefly, the basic pan evaporation measurements were converted to reference evapotranspiration (ETo) records using Eq. 1, where Kp is the pan coefficient which takes into account the type of the pan, its environment and climate (Doorenbos and Kassam 1979). Crop evapotranspiration (ETc; mm) was calculated from potential evapotranspiration (ETo; mm) based on micrometeorological data obtained from the weather stations using Eq. 2, where Kc is the crop coefficient which depends on the crop under consideration and stage of development (Allen et al. 1998)

Equation 1 $$ETo = Kp \times Epan$$

Equation 2 $$ETc = Kc \times ETo$$

By substituting Eq. 1 in Eq. 2 the following Eq. is obtained:

Equation 3 $$ETc = Kp \times Kc \times Epan$$

The procedure described so far is the general one suggested by FAO and values of the coefficients to be used can be derived from the literature (FAO Irrigation and drainage paper 56). However, in Cyprus the value of Kp coefficient for a specific area is constant over the irrigation season (April to November); its values are 0.85 for the inland and coastal plain areas and 0.75 for the mountain areas (Metochis and Orphanos 1997). Therefore, the product Kc x Kp in Eq. 3 can be substituted by the single coefficient C. The resulting equation is:

Equation 4 $$ETc = C \times Epan$$

where, $C = Kc \times Kp$

Crop parameters, however, were adjusted under local climatic conditions and crop management practices. The C coefficient values have been extensively studied for a long period in field experiments conducted at the Agricultural Research Institute of Cyprus, and vary among plant species, as well as among plants' growth stage (Metochis, 1997). Particularly, the C value for apple trees it ranges from 0.4 during spring to 0.6-0.7 during the summer and autumn. Moreover, in order to compute the net irrigation requirements (NIR) of the crops, the effective rainfall during the growing period was subtracted from actual water requirements (ETc values) and the results are presented in Table 1

Table 1. Monthly irrigation requirement (m3/10000 m2) in the area of Kyperounta

| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Efective rainfall ($m^3$/ha)** | 631 | 454 | 328 | 112 | 52 | 43 | 16 | 8 | 8 | 107 | 366 | 701 | |
| **Water needs ($m^3$/ha)** | 0 | 0 | 0 | 0 | 628 | 1758 | 1806 | 1804 | 825 | 0 | 0 | 0 | 6821 |
| **Irrigation needs ($m^3$/ha)** | 0 | 0 | 0 | 0 | 575 | 1715 | 1790 | 1796 | 816 | 0 | 0 | 0 | 6694 |
| **Irrigation events ($m^3$/ha)** | | | | | **1** | **3** | **6** | **5** | **3** | | | | **18** |

## Ways of better usage of water resources

To avoid the detrimental effects of water deficit on apple yields and quality organic farmers should employ specific strategies and practices. In this section we describe the different tools that should be included in the irrigation management scheme under the realities and the climatic conditions of Cypurs apple organic farming sector. These tools could be used supplementary to the well established and locally callibrated evapotranspiration scheduling method.

### Soil Moisture Monitoring

The implementation and the adoption of soil moisture monitoring techniques it is expected to increase the water use efficiency of the apple orchards. Soil water availability directly affects plant water uptake and the availability of such information could be used to schedule irrigation of the orchards. For example, the installation of tensiometers for the indirect measurement of soil moisture tension could provide important information regarding soil water conditions while soil salinity is not affecting the readings and the decision making of the farmer. In each measurement location in the field, at least two tensiometers of different length should be installed in the zone of greatest root density and at about 1/4 to 1/3 of the functional root depth of the trees (usually 20 to 60 cm).

### Crop Management Practices

Crop management practices that are affecting plant biomass production could be improved tailored to the water needs of the crop. For example, nitrogen based fertilization strategy increases shoot biomass production thereby increasing water uptake and transpiration. Instead, incorporation of composts and stable organic carbon in soils gradually improves the water holding capacity of the crop. Thus the sustainable nutrient managment will also enhance water use efficiency particularly under water limited conditions. Prunning and fruit thining are important practices affecting water needs of the crop. During drought periods, farmers should perform heavy pruning particularly in trees with low yields to reduce their water needs. Similarly, thining is a practice that could substantially improve water use efficiency of the trees due to the competition reduction within trees for water during the fast growing stage of the fruits. Soil mulching and sustainable weed management is expected to reduce water evaporation and deminish the competition between weeds and apple trees. In particular, mechanical incorporation of summer weeds with-in rows is expected to reduce the competition for water resources.

## Reduced irrigation methods in organic apple orchards

Regulated Deficit Irrigation, is a technique that purposely stresses crops during certain growth stages to reduce evapotranspiration without significant reduction of crop yield or quality. The aim of this approach is to reduce vegetative growth along with some beneficial effects on fruit quality through the induction of controlled water stress conditions. It has been demonstrated that regulated deficit irrigation (RDI) could increase water saving in fruit orchards thereby minimizing nutrient losses which is fundamental for organic farming systems. The main factors controlling the success of RDI are timing and water regime level and crop growing characterestics. The main drawback of implementing RDI in apple orchards is that the vegetative and reproductive growth occur concurrently (Forshey et al., 1983) and water deficit reduces fruit size and crop yields irrespectively time (Ebel et al., 1995; Mpelasoke et al., 2001).

Partial Rootzone Drying (PRD) is another irrigation approach during which only one half of the rootzone is irrigated in a sequential way. Previous studies in apples showed that this methodology is superior to RDI and allows good fruit final size and yields along with significant reduction of water inputs (Caspari et al., 2004; Einhorn and Caspari, 2004; Lombardini et al., 2004). The success of this method relies on the hormonal signaling that is induced from the stressed part of the roots and the coccurent water uptake from the roots that are normally irrigated. In particular, during water stress ABA is translocated to the leaves and triggers a partial stomatal closure to reduce transpiration. The detrimental effects of water shortage in plant water potential is minimal since plants are receiving water maintaining this way vital physiological and metabolic processes. In practice, the implementation of RDP is applied in cyclical wetting and drying of plants rootzone to maintain root-derived ABA signals (Zhang and Davies, 1987).

The implementation of reduced irrigation methods relies on an advanced knowledge of plant growth and soil characteristics as well as environmental conditions. The implementation either RDI neither PRD.

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## Case study for irrigation scheduling for regulated deficit irrigation for apple orchards

As a case study we present a mature apple organic orchard located in Kyperounda area at Troodos according to the data presented in Table 1.

| | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|
| **Efective rainfall ($m^3/ha$)** | 52 | 43 | 16 | 8 | 8 |
| **Water needs ($m^3/ha$)** | 628 | 1758 | 1806 | 1804 | 825 |
| **Irrigation needs ($m^3/ha$)** | 575 | 1715 | 1790 | 1796 | 816 |
| **Irrigation events ($m^3/ha$)** | **1** | **3** | **6** | **5** | **3** |

Before implementing RDI trees rootzone should be de-watered and trees are sustained during regulated deficit irrigation by frequent, low volume irrigation events that are appropriate to provide water only the upper are of the root zone. Thus it is critical for the farmer to calculate the time during May that should keep trees without irrigation. In this orchard, the rooting depth was 65 cm and the with a total number of plants per hectare 21 (7x7m) thereby the root-zone of each tree has a volume of:

$$0.65(\text{m}) \times 10000\ (\text{m}^2) \div 210\ (\text{trees/ha}) = 30952\ \text{L.}$$

The readilly available water in sandly clay loam soil is 6% while the deficit-available water of the soil that can be extracted is 5% assumes that the total water resource (TWR) in this field for each tree is:

$$\text{TWR} = 30925\text{x}6\% + 30952\text{x}5\% = 3404\ \text{L per tree}$$

During 2017 the Pan Evaporation during May was 36.2 mm/week with an initial C crop factor of 0.6 crop evapotranspiration will be

$$36.2\ \text{mm/week} \times 0.6 = 21.7\ \text{mm/week}$$

this equals to 217200 L/week in one hectare and corresponds to 1034 L/tree/ week. Since the available water for each tree is 3404 L then this amount could sustain apples evaportranspiration for during this initial phase for 3 to 4 weeks. During this period, trees will be gradually stressed and the crop factor should be adjusted and canopy transpiration is constrained (C=0.3 or 0.4). In the current scenario we assumed a crop factor equal to 0.4. According to these calculations, then the irrigation schedule for this orchard should be as follows:

| | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|
| **RDI ($m^3$/ha)** | 0 | 879 | 1190 | 1190 | 544 |
| **Irrigation events ($m^3$/ha)** | **0** | **4** | **4** | **4** | **4** |

## Conclusions

Irrigation is a fundamental practice to maintain productivity and quality of organic apple orchards. The irrigation strategy should aim to increase the use efficiency of this valuable resource without reducing crop productivity and quality. In Cyprus, most of the organic apple farmers have already installed improved irrigation systems thereby reducing the amount of water needed for the crop. The irrigation needs of the crop are calculated according the methodology developed and suggested by FAO. However, there is ample scope for improving water use and irrigation management in organic apple orchards. For example, the inclusion of soil moisture monitoring systems to optimize the irrigation scheduling it is expected to further improve the water use efficiency of organic apple orchards. Practices like mulching, pruning and fruit removals at a proper growth stage, compost incorporation and reduced N inputs is also expected to improve water use efficiency of the crop. Regulated deficit irrigation practices could be included in the organic farming practices. There is a substantial amount of evidence that this technique could increase water use efficiency and reduce the amount of water needed without reducing apple yield and quality. However, multiyear studies are necessary to establish a well design DRI schedule since perennial crops require time to acclimatize to a reduced amount of water. Legacy effects of soil water are also affecting next year productivity.

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