Drip-irrigation use in Northern Guanajuato, Mexico

An evaluation in the broccoli production sector

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"Drip-irrigation use in Northern Guanajuato, Mexico: An evaluation in the broccoli production sector."

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Abstract

Drip irrigation is widely promoted as a water saving tool, but there is little literature on the performance of this technology under field conditions in developing countries. The little evidence there is suggests that over-irrigation and other irrigation efficiency constraints are prevalent, keeping irrigation efficiencies of drip irrigation low. In this context drip irrigation practices and systems were investigated at 5 large-scale broccoli producers in the Independence Aquifer in Northern Guanajuato, Mexico. System uniformities, and irrigation schedules were evaluated. CROPWAT simulations were done and later compared to actual irrigation in the field to demonstrate the difference between desirable and actual irrigation patterns. Research results show that system performances were poor and farmers systematically over irrigate. Interviews, measurements and CROPWAT calculations all show that producers are not using drip irrigation as a water saving tool, but as a labour-saving technology. Drip irrigation is also used to ensure ideal crop growth conditions, increase cropping intensity and reduce the danger of yield loss. The study questions the water use efficiency assumptions that are usually associated with drip irrigation and offers insights that can be interesting for further policy decisions concerning irrigation subsidies and state investment in developing countries.

Samenvatting

Druppel irrigatie staat algemeen bekend als een water besparende technologie, maar in de wetenschappelijk literatuur is weinig bekend over de daadwerkelijke water besparing in ontwikkelingslanden. In de literatuur dat er wel is word gesuggereerd dat er vaak te veel word geïrrigeerd en dat andere efficiëntie beperkingen optreden waardoor de irrigatie efficiëntie toch laag blijft. In deze context zijn 5 grootschalige broccoli producenten in de Independence aquifer in noord Guanajuato, Mexico onderzocht. Als deel van dit onderzoek zijn systeem uniformiteit en irrigatie schema's zijn geëvalueerd. Simulaties met CROPWAT zijn gedaan en vergeleken met de daadwerkelijke veld irrigatie om de verschillen te bepalen tussen de wenselijke en daadwerkelijke irrigatie schema's. De resultaten van dit onderzoek laten zien dat het systeem niet goed presteert en dat er systematisch te veel word geïrrigeerd. Interviews, metingen en de CROPWAT simulaties laten zien dat de broccoli producenten druppel irrigatie niet gebruiken als een wat besparende, maar als een arbeid besparende technologie. Verder word druppel irrigatie ook gebruikt voor om ideale gewas groei condities te realiseren, gewas intensiteit te verbeteren en om de oogst verliezen te beperken. Dit onderzoek betwijfelt de aannames wat betreft efficiëntie die vaak gedaan worden in relatie tot druppel irrigatie. Dit onderzoek zal ook inzichten geven die interessant kunnen zijn voor het maken van beleid wat betreft irrigatie subsidies en staats investeringen in ontwikkelingslanden.

Zusammenfassung

Tröpchenbewässerung wird weltweit als ein Instrument zur Wassereinsparung beworben, obwohl es kaum wissenschaftliche Studien unter realen Bedingungen dieser Technologie in

Entwicklungsländern gibt. Die bisher vorhandenen Studien weisen darauf hin, dass exzessive Bewässerung und andere Faktoren die tatsächliche Effektivität stark reduzieren. Vor diesem Hintergrund wurden 5 Farmen in Guanajuato, Mexiko untersucht und die Bauern befragt. Untersucht wurden die Uniformität der Wasserverteilung sowie die von den Produzenten entworfenen Bewässerungspläne. Interviews, Beobachtungen und Berechnungen mit Hilfe der CROPWAT Software zeigen, dass Tröpchenbewässerung zur Vermeidung und Reduzierung von manueller Arbeit eingesetzt wird. Auch ist es für die Bauern von höchster Bedeutung die Pflanzen niemals Wasserstress auszusetzen. Diese Studie stellt die einhellige Meinung in Frage, dass Tröpchenbewässerung ein adäquates Mittel zur Verbesserung der Wassserersparnis darstellt.

Resumen

El riego por goteo es ampliamente promocionado como una herramienta de ahorro de agua, pero hay poca literatura sobre el rendimiento de esta tecnología en condiciones de campo en los países en desarrollo. La escasa evidencia disponible sugiere que el exceso de riego y otras limitaciones de eficiencia de riego son frecuentes, manteniendo las eficiencias de riego de bajo riego por goteo. En este contexto goteo prácticas y sistemas de riego se investigaron a los 5 productores de brócoli a gran escala en el acuífero de la Independencia en el norte de Guanajuato, México. Se evaluaron uniformidades del sistema y los programas de riego. simulaciones se realizaron CROPWAT y más tarde en comparación con el riego real en el campo para demostrar la diferencia entre los patrones de irrigación deseables y reales. Las investigaciones realizadas indican que los rendimientos del sistema eran pobres y los agricultores de forma sistemática durante riegan. Entrevistas, mediciones y cálculos CROPWAT todos muestran que los productores no están utilizando riego por goteo como una herramienta de ahorro de agua, sino como un ahorro de trabajo la tecnología. El riego por goteo se utiliza también para garantizar las condiciones de crecimiento de cultivos ideales, aumentar la intensidad de cultivo y reducir el peligro de la pérdida de rendimiento. El estudio cuestiona los supuestos de eficiencia de uso del agua que se asocian generalmente con conocimientos de riego por goteo y ofertas que pueden ser interesantes para futuras decisiones de política relativas a los subsidios para riego y la inversión del Estado en los países en desarrollo.

Abbreviations

CFE=Comisión Federal de Electricidad
CNA= Comision Nacional del Agua
CONAGUA=CNA
CWR= Crop water requirements
COTAS= Consejos Técnicos de Aguas
DP= Deep percolation
DU= Distribution uniformity
ETc= Crop Evapotranspiration
ETo= Reference Evapotranspiration
FC= Field capacity
IWRM=Integrated water resource management
Kc = Single crop efficient
LAN= Ley de Aguas Nacionales
MRQ= Main research question
RO= Runoff
SRQ= Sub research question
TAW= Total available water
USDA= United States Department of Agriculture
WP =Wilting point

1. Introduction and research background

1.1.1 Irrigation connected with Acuífero de la Independencia or of the Aquifer of Rio Laja.

The goal of this master thesis is to contribute to a better understanding of the performances (in terms of water use efficiency at plot level, and in terms of the broader farm production process) of drip irrigation when used by farmers in field conditions, since there is no data for this in Mexico. It will do so by analysing irrigation practices and efficiency on 5 broccoli-producing farms around Dolores Hidalgo, Guanajuato, Mexico. The results will show drip irrigation realities and give an indication of how drip irrigation systems are run in real life conditions.

Guanajuato, which is a state and a city within the United States of Mexico, is in the geographic centre of Mexico. Around the city are some of the most important national agricultural zones, with agriculture being the biggest single productive activity in the state. The agricultural sector is responsible for most of the local water consumption, utilizing up to 87% of all surface and underground water in the state (Longoria & Barrett, 2013)

Map 1 Dolores Hidalgo inside of Guanajuato, Mexico

The CNA was expected to reduce ground water overexploitation and stop the dramatic reduction of ground water levels, which are currently declining by 2m/year on average (Wester, Hoogesteger, & Vincent, 2009). As part of implementing the governmental irrigation recommendations they also promote irrigation modernisation in the area. Brochures and consultants are promoting the shift to drip irrigation.

Due to climate change and a growing economy, water is becoming more and more scarce (Longoria & Barrett, 2013). This causes a permanent overexploitation of aquifers. Reaching sustainable groundwater extraction has been the most important issue during the last decade (Wester, Hoogesteger, & Vincent, 2009). Studies from 1997 show that already at that time, 17 of the aquifers in the region were overexploited (Johnson, 1997). Today the situation is even worse, since all of the 18 aquifers are overexploited, with annual extractions of roughly 1,200 million m^3 more than recharge. Total groundwater extractions sum up to 4100 million m^3 (Wester, 2008). Of the total water extracted, 80% are used for irrigation, 18% by households and 2% for industrial purposes. Another problem than aquifer depletion is the over-fertilization with nitrogen and phosphorus, causing water quality problems (Peña-Cabriales & Castellanos, 1990). Farmers tend to apply fertilizers excessively, without considering the potential leaching of nitrates into the active root zone. Castellanos & Peña (1990) report that an average of 25-50% of nitrogen applied for most crops was leached out of the root zone.

Nevertheless, there are case studies that show that specific irrigation systems in the state are not working as efficiently as projected (Buendia-Espinoza, 2004). In the case of drip irrigation, which has been promoted as a successful method for efficient water use in developing and developed countries since the end of the Second World War (Belder, Rohrbach, Twomlow, & Senzanje, 2007), it becomes more and more obvious that there is a discrepancy between the projected performance and the actual performance in the field. The goal of this thesis is to investigate farmer's practice and actual irrigation efficiency at plot level on five farms with five different owners and irrigation staff.

1.1.2 The drip irrigation debate

Over the last 30 years, concerns about the scarcity of water have focussed on irrigation, the biggest water-using factor, which is mostly perceived as a low-value, wasteful and "inefficient" use for water. The terminology for this debate is, however, poorly defined – often failing even to distinguish between consumptive and non-consumptive use. One of the results of this is that technical interventions have not always led to the expected, desirable outcomes, and the recommendations in many reports and papers are at best dubious, at worst simply wrong (Perry, 2007). There is a strong belief among most scientists and researchers that drip irrigation holds a vast potential for water savings and improvements in water productivity in various crops, such as most vegetables, cotton, orchards and others (Indian National Committee, 1994; Sivanappan, 1994). Drip irrigation is considered to be the ultimate tool in international politics to save water and

increase crop per drop (Abric et al., 2011). A report by the World Bank even considers drip irrigation to be “between 90% and
95 % efficient” (2011). However, these figures, even if they appear to be backed up by important scientific factors, have recently been contested (Van der Kooij et. al, 2013).
The main debate in irrigation studies is about the definition and use of the term water efficiency. There is currently no consensus about the definition of irrigation efficiency and its use within the scientific community (Halsema & Vincent, 2012)
Since this work is focussed on irrigation practices under field conditions, there is a need for a simple definition that can be investigated with the given tools. The ratio between irrigation water actually utilized by the crops and the water supplied by the pumps is the definition of irrigation efficiency. (ETc divided by total water applied).
The question of what happens to the water that is not used by the plants is not a concern in this thesis. There are several scenarios concerning what could happen to the water. Firstly, it is possible, that it percolates into the groundwater, and therefore replenishes the aquifer. This would mean that the water can be reused by other farmers in the same basin. Even if this is the case, agricultural groundwater contamination which is being transported to the aquifer remains a problem.
This is a hands-on and practical definition that enables me to conduct an inexpensive and effective piece of research.
Nevertheless, it is important to acknowledge that the subject of water saving is controversially discussed within the scientific community.

As shown above, it is difficult to ultimately judge the contribution of drip irrigation to water savings. Even if there is plenty of literature about drip irrigation performance, Van der Kooij et al. (2013) find it striking that the vast majority of irrigation research is carried out under laboratory or experimental conditions, while there is a knowledge gap in water efficiency research on operating farms: Most reviewed articles (44 out of 49) describe experiments with drip irrigation set up at research institutes, one article shows the results of a water distribution model (Barragan, Cots, Monserrat, & Lopez, 2010) and only three other articles (Thompson, Pang, & Li, 2009); (Kumar, et al., 2009); (Maisiri, Senzanje, Rockstrom, & Twomlow, 2005) look at drip irrigation as used by farmers. They draw the conclusion that efficient water use is seldom an important factor for farmers when planning their irrigation schedule. Kumar et al (2009) conclude that there are improvements in irrigation efficiency, but that the actual improvements are highly dependent on specific conditions such as terrain, soil and the setup of the system. These studies also investigate small and medium-scale agriculture, whereas this research was undertaken on medium- and large-scale farms of between 63 and 150 hectares.

Furthermore, field investigations for drip irrigation are always problematic, since they require sophisticated means of evaluation to be precise, and these are often not available. Since most current field condition irrigation studies use simple instruments, there is a lot of uncertainty about the precision of their results.

Another issue concerning field irrigation studies is that the topic is highly complex. There is no consensus about the definitions of the terms used in various papers. An additional uncertainty is that some scientists include social factors, some economic, and some none. Most studies try to investigate as much as possible. Recently, European scientists have recognized an urgent need for a universal study about the different impacts and side effects of investment and the resulting shift in irrigation modernization. (Lopez-Gunn, Zorrillac, Prietod, & Llamase, 2012) These different paradigms and priorities make it difficult to compare results and create synergies.

Recently, studies funded by the WWF and other bodies have concluded that irrigation modernization did, in fact, increase water consumption in dry areas such as southern Spain. None of the screened projects has ultimately saved water; rather, their effect was to increase water consumption between +4% and +42% compared with previous levels. (Cebollada, 2013).

Other studies conclude that the effect of irrigation modernization is highly dependent on adequate management and operation of the systems. If policies only subsidize irrigation modernization and not water accounting, the benefits are questionable (Lecina et al., 2010)

In my opinion, there is a need for the most basic investigations about what farmers do in the field and why they do it. It is obvious that in different parts of the world there are different approaches towards agriculture, nevertheless, collecting basic data and evaluating it can help contribute to a better understanding of why drip irrigation systems often perform in reality differently from the way that they were expected to.

There is evidence that for farmers it is often most important to reduce labour costs and be able to irrigate previously inaccessible land. (Sese Mínguez, 2012)

1.2. Objectives and knowledge gap

As mentioned above, technology and its use is a result of social construction.

It is the job of an engineer to adjust the technology, and to maximise the benefits that can be derived. This requires extensive groundwork and evaluation of data, which is what I intend to do in this research thesis.

As stated earlier, the idea of drip irrigation being a panacea for water scarcity problems is becoming more and more contested. There is a knowledge gap concerning drip irrigation performance under field conditions, when run by farmers outside of Europe. The scientific objective of this thesis is to contribute to the knowledge and to begin to close this gap.

Promoters of drip irrigation claim that irrigation efficiencies of more than 90% are possible by using drip irrigation. While this is certainly true under laboratory conditions or in a controlled environment, in the case of drip irrigation in Guanajuato, little is known about irrigation performance and the motivation of farmers behind the systems.

1.3. Problem statement and research questions

It has become clear that there is a lively discussion within the irrigation community about the term water efficiency. The conclusion of the current discussion is that there is a knowledge gap about how drip irrigation works in field conditions, with farmers operating it, not researchers.

Little is known about farmer's practices using drip irrigation and how these affect the performance of plot level drip irrigation systems in Guanajuato, Mexico.

Starting from this problem statement, one main research question can be defined:

MRQ: How do farmers' rationales (the result of their decisions and motivations) affect the condition of their drip irrigation equipment, the drip irrigation practices and related irrigation management in broccoli production in the state of Guanajuato, Mexico?

SRQ1: How do farmers and operators run their systems (differently) and what are the decisions of farmers to operate their drip irrigation system in the way they do?

SRQ2: In what condition are the drip irrigation systems and how do they perform in terms of distribution uniformity and total water applied?

SRQ3: What is the difference between the amount of irrigation on the field, the calculated projected irrigation efficiency and the irrigation needs calculated by CROPWAT

2. Material and Methods

2.1. Irrigation performance and distribution uniformity

The distribution uniformity will also be evaluated. DU gives an indication of the technical condition of the system. Systems that are badly maintained or of an inferior quality tend to have smaller distribution uniformity coefficients. Also, an uneven distribution of water is an indicator for either over- or under-irrigation. For the evaluation of drip irrigation systems, there is a detailed measuring instruction by (Burt et al., 2004):

(Burt et al., 2004) identify four important criteria, of which two are used for this evaluation:

1. Pressure differences. Pressure differences between emitters will cause flow rate differences as described by the relationship q = k p x. Since it is impossible to conduct pressure measurements without damaging the system, discharge measurements will be made to get an indication of the pressure differences.

2. "Other". This refers to any factor that would cause flow rate differences among emitters even though the emitters are all at the same pressure. Such factors include plugging (by minerals, dirt, insects, etc.), wear (such as occurs with heavy applications of gypsum through micro sprayers), and manufacturing variation.

For investigating the criteria that influence the distribution uniformity of an irrigation system, the following methodology was used, which is slightly modified and was designed by Burt (2004).

The methodology requires pressure measurements that are not possible without damaging the system. Since pressure and discharge are closely related, I will conduct discharge measurements instead of pressure measurements.

1. Discharge along individual hoses: Three measurements are made along each hose that is selected:

    1. At the head of the hose
    2. Halfway down the hose (hydraulic)
    3. At the end of the hose

It could be argued that more than 75% of the friction of the hose occurs upstream of the midpoint of the hose. However, if one considers the wide range of topography encountered along drip, and the tremendous range of pressure distribution patterns that result, the middle of the hose is a reasonable location for a discharge measurement.

Other causes of non-uniformity include anything other than pressure differences that could cause a flow rate difference between emitters while the system is pressurized. In the field, it is impractical to quantitatively distinguish between the effects of clogging, wear, and manufacturing variation. It is possible, however, to distinguish qualitatively through observation of cut-apart emitters and the type of filtration, questions about chemical injection, and observation of what flushes out from hose ends and for how long.

At each location, there must be no pressure difference between the individual emitters, if no pressure compensating emitters are installed. The pressures can be different at each location. The three locations are:

1. The head of a hose in an area of the field that is estimated to have the “cleanest” emitter. This is generally on a hose that is hydraulically close to the water source. Individual flow rates are taken from 16 emitters. This is the location of the two discharge tests that are needed to determine the emitter discharge exponent
2. The middle of a hose in the middle of a manifold that is near the middle of the field. This might be considered a “typical” location. Individual discharge rates are taken from 16 emitters.
3. The end of a hose at the end of the most distant manifold. This is typically the dirtiest point in the field. Because of the larger variation in flow rates between emitters in this location, the sample size must be larger: 28 emitters rather than 16.

Following Burt et al (Burt, et al., 1997)The distribution uniformity is then calculated using the following formula. To demonstrate the difference between distribution uniformity and irrigation efficiency, DU will be given as a ratio, not as a percentage. The lowest quartile of the measurements is used to calculate the average lower quarter depth.

$$Dlq = \frac{vol.\,accumulated\ in\ 1/4\ total \text{ of elements with smallest depths}}{\text{¼ of the total area of elements}}$$

$$DUlq = \frac{average\ low\ quarter\ depth}{average\ depth\ of\ water\ accumulated\ in\ all\ elements}$$

2.2. Socio-technical approach and irrigation practices

"Both human and physical aspects interact continually and profoundly in irrigation enterprises, so a hyphenated construct of irrigation as a socio-technical process seems appropriate." (Uphoff, 1986)

Acknowledging that technology also has social implications and is ultimately an expression of human organization in networks leads directly towards the socio-technical approach.

This also means, that a technical intervention will always affect social structures; therefore, the researcher becomes a part of the network.

A socio-technical approach acknowledges that social implications and technological changes are directly interrelated. Both need to be analysed to ensure accurate and concise research. From this scientific perspective, it can be easily derived that technology is not the famous "black box", and there are no societal and personal values and consequences attached to it. There are social requirements for its use (Mollinga P. , 1998). Societal changes can drastically influence technological development and the use of technology and vice versa. Chapter 3 shows how the ideas of Mollinga are applied to this case.

To apply these concepts to the study area in Guanajuato, I will use the work of (Mollinga P. , 1997), who defined 4 important criteria to analyse irrigation practices. (Hoogesteger, 2004) applied Mollinga's concept to groundwater irrigation in Guanajuato. His findings are the basis for the following paragraphs.

1.Human agency: The arena of human agency is complex. The rationale under which farmers produce is influenced by their cultural context and their experience. The scope of this research is how human agency (without exploring it) determines the way irrigation systems are set up and operated. What are the consequences that occur because of the specific human agency amongst the farmers and system operators in my research?

The human domain contains the set of ideas that users have in mind regarding how drip irrigation should work. This defines their actions. Since technology is always operated by humans, the attitude and motivation of these operators will always define the way the technology is used and its results. Since there is a tendency to associate drip irrigation technology with water use efficiency and water savings in the scientific community and at state level, it is important to keep in mind that farmers might buy and invest in drip irrigation technology rather to save labour, apply fertilizer and intensify their production patterns than to save water. The set of ideas determining how farmers want to use their equipment is human agency.

2. Strategies and resources: The strategy of a stakeholder is highly dependent on his objective. In most cases in Guanajuato, the objective is to create a livelihood for their families and themselves from irrigated agriculture (Hoogesteger, 2004). In this case, resources are usable land, access to water, technologies such as drip irrigation systems and fertigation systems and related systems and other resources such as agricultural production inputs (fertilizers, machinery, workforce).

3. Arenas or domains of interaction: There are countless levels, ways and arenas of interaction between farmers. In the context of this research, the field level is important, where farmers interact with their given resources to produce outcomes. Technology plays an important role, and often influences the behaviour of stakeholders (Hoogesteger, 2004).

Due to droughts in the southern states of the US and the low Peso, producers find themselves in a situation where they achieve high revenues for exporting vegetables to the US and Japan. Farmers state, that broccoli for the Japanese market has to be smaller than that for the US market. This allows for more plants on a plot. Since there is no effective control over ground water resources in this area, it is profitable for farmers to pump water up to a point, where they can be absolutely sure that there is no scarcity whatsoever. This combination of internal and external factors is a strong motivation to use to water to produce as much as possible.

4. Rules and routines: Within every society, there is a set of rules and routines that stakeholders follow either willingly or unconsciously. To understand the mechanisms of these routines it is crucial to understand the stakeholder's behaviour in a certain context.

Looking at the different aspects of irrigation practices will create rich picture of irrigation practices in Guanajuato at farm level.

A lot of the rules and routines that lead to farmer's decisions are defined in an unofficial way. It is common for farmers to sit together or meet for a drink during the day or in the evenings. These important social gatherings are mainly an opportunity to talk about their farms, to discuss prices and production patterns.

It is interesting to see that the routines often differ from what farmers think the rules are. While talking to the operators, I found out that they mainly work based on their experience. This means that they turn off the water when they feel that there is absolutely no chance that there might be underirrigation.

The questions that were derived from this framework are included in the appendix.

Interviews were conducted with all the farmers who own the farms and with the operating staff of the systems in order to evaluate the way the systems are run. In addition, to semi-structured interviews, information given by farmers without being specifically asked for it is also included in the farmer's stories. I consider it to be important to be flexible, because my personal experience has shown that the reality often looks different than that projected from the desk.

2.3. CROPWAT

CROPWAT is a software designed for the calculation of the adequate quantity of water required for agricultural production. The calculation strategy is based on two publications by the same developer: the "Crop Evapotranspiration" guide that presents a procedure for the calculation of the efficient quantity of crop water, and "Yield response to water", which presents an analysis on crop yield as a result of water use. (FAO, 2016)

Programme structure:

The CROPWAT programme is organised in 8 different modules, of which 5 are data input modules and 3 are calculation modules. This allows the user to easily combine different climatic, crop and soil data for calculation of crop water requirements, irrigation schedules and scheme supplies.

The relevant data input modules of CROPWAT are:

2.3.1. Climate/ET_0

The concept of ET_0 was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development and management practices. As water is abundantly available at the reference evapotranspiring surface, soil factors do not affect ET_0. Relating the evapotranspiration process to a specific surface provides a reference to which evapotranspiration from other surfaces can be related. It obviates the need to define a separate evapotranspiration level for each crop and stage of growth. ET_0 values measured or calculated at different locations or in different seasons are comparable as they refer to the evapotranspiration from the same reference surface.
ET_0 can be computed from meteorological data. Because of an Expert Consultation held in May 1990, the FAO Penman-Monteith method is now recommended as the standard method for the definition and computation of the reference evapotranspiration. The FAO Penman-Monteith method requires radiation, air temperature, air humidity and wind speed data. Calculation procedures to derive climatic parameters from meteorological data and to estimate missing meteorological variables required for calculating ET_0 are presented in Chapter 3. The calculation procedures used here allow for the estimation of ET_0 with the FAO Penman-Monteith method under all circumstances, even in the case of missing climatic data. (FAO)

The only factors affecting ET_0 are climatic parameters. Consequently, ET_0 is a climatic parameter and can be computed from weather data. ET_0 expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider crop characteristics and soil factors.

The Climate/ET_0 module is data input, requiring information on reference evapotranspiration (ET_0). When ET_0 is provided this way, no calculation is carried out by CROPWAT.

ET_0 data was taken from smn.cna.gob.mx. Averages were calculated for the years from 1981-2014. The relevant station is “**Peñuelitas”.**

2.3.2. Rain: input of rainfall data and calculation of effective rainfall;

For agricultural production, effective rainfall refers to that portion of rainfall that can effectively be used by plants. Not all rain is available to the crops as some is lost through runoff (RO) and deep percolation (DP).

How much water actually infiltrates the soil depends on soil type, slope, crop canopy, storm intensity and the initial soil water content. Rainfall is highly effective when little or no RO occurs. Small amounts of rainfall are not very effective, as these small quantities of water are quickly lost to evaporation.

As input of monthly rainfall, the average reliable or actual rainfall data can be used. Care should be taken in selecting appropriate values for reliable rainfall, based on separate statistical analyses of long-term rainfall records.

Rainfall data was taken from smn.cna.gob.mx. Averages were calculated for the years from 1981-2014. The relevant station is “**Peñuelitas”.**

2.3.3. Crop: the input of crop data and planting date;

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapotranspiration under standard conditions (ET_c) and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration.

Differences in leaf anatomy, stomatal characteristics, aerodynamic properties and even albedo cause ET_c to differ from ET_0 under the same climatic conditions. Due to variations in crop characteristics throughout the growing season, K_c for a given crop changes from sowing till harvest.

Crop evapotranspiration can be calculated from climatic data and by integrating directly the crop resistance, albedo and air resistance factors in the FAO Penman-Monteith approach. As there is still a considerable lack of information for different crops, the Penman-Monteith method is used for the estimation of the standard Reference crop to determine its evapotranspiration rate, i.e., reference evapotranspiration (ET_0). Experimentally determined ratios of ET_c/ET_0, called crop coefficient (K_c), are used to relate crop evapotranspiration under standard conditions (ET_c) to ET_0. This is known as the crop coefficient approach.

$ET_c = K_c * ET_0$

Radiation, air temperature, humidity and wind speed are all incorporated into the ET_0 estimate. Therefore, ET_0 represents an index of climatic demand, while K_c varies predominately with the specific crop characteristics and only to a limited extent with climate and soil evaporation. This enables the transfer of standard values for K_c between locations and between climates. This has been a primary reason for the global acceptance and usefulness of the crop coefficient approach and the K_c factors developed in past studies

2.3.4. Soil: for the input of soil data

Initial available soil moisture

Initial available soil moisture is defined as the soil moisture content at the start of the growing season. It is calculated as the product of the total available water (TAW) by the initial soil moisture depletion, and expressed in mm per metre of soil depth.

Initial soil moisture depletion

The initial soil moisture depletion indicates the dryness of the soil at the start of the growing season, that is, at seeding in case of non-rice crops, or at the beginning of land preparation in case of rice. Since all the farmers fill up the soil to field capacity at the beginning of the irrigation cycle, the initial soil moisture is always 100%.

The initial soil moisture depletion is expressed as a percentage of the total available water (TAW), in terms of depletion from field capacity (FC). The default value of 0 % represents a fully wetted soil profile at FC, 100 % is a soil at wilting point (WP).

In most cases, only an estimate can be made of the initial soil moisture condition, depending on previous crop and periods of a preceding fallow or dry season period.

Maximum infiltration rate

The maximum infiltration rate, expressed in mm per day, represents the water depth that can infiltrate the soil over a 24-hour period, as a function of soil type, slope class and rain or irrigation intensity. The maximum infiltration rate has the same value as the soil hydraulic conductivity under saturation.

The maximum infiltration rate allows an estimate of the runoff (RO), occurring whenever rain intensity exceeds the infiltration capacity of the soil.

Maximum rooting depth

Although in most cases the genetic characteristics of the crop will determine the rooting depth, sometimes the soil and certain disturbing soil layers may restrict the maximum rooting depth. This is the case, for example, when hardpans exist in fields where mechanised practices have not been managed adequately. In rice fields, the hardpan is instead intentionally created in order to diminish percolation losses and this limits the rooting depth of the crop

The maximum rooting depth is expressed in centimetres. The default value is set arbitrarily at 900 cm, indicating soil with no significant characteristics that can restrict root growth. Any value lower than crop rooting depth would indicate a limitation to root growth. For this thesis, rooting depth was estimated at 45 cm. This value can be found in literature (USDA, 2005) While being on the field I confirmed, that there are no soil layers which obstruct root growth up to this depth in the relevant plots.

All soil samples were either analysed by a specialist laboratory in Mexico, or were classified by a group of soil specialists at Wageningen University under the supervision of Fokke Brouwer.

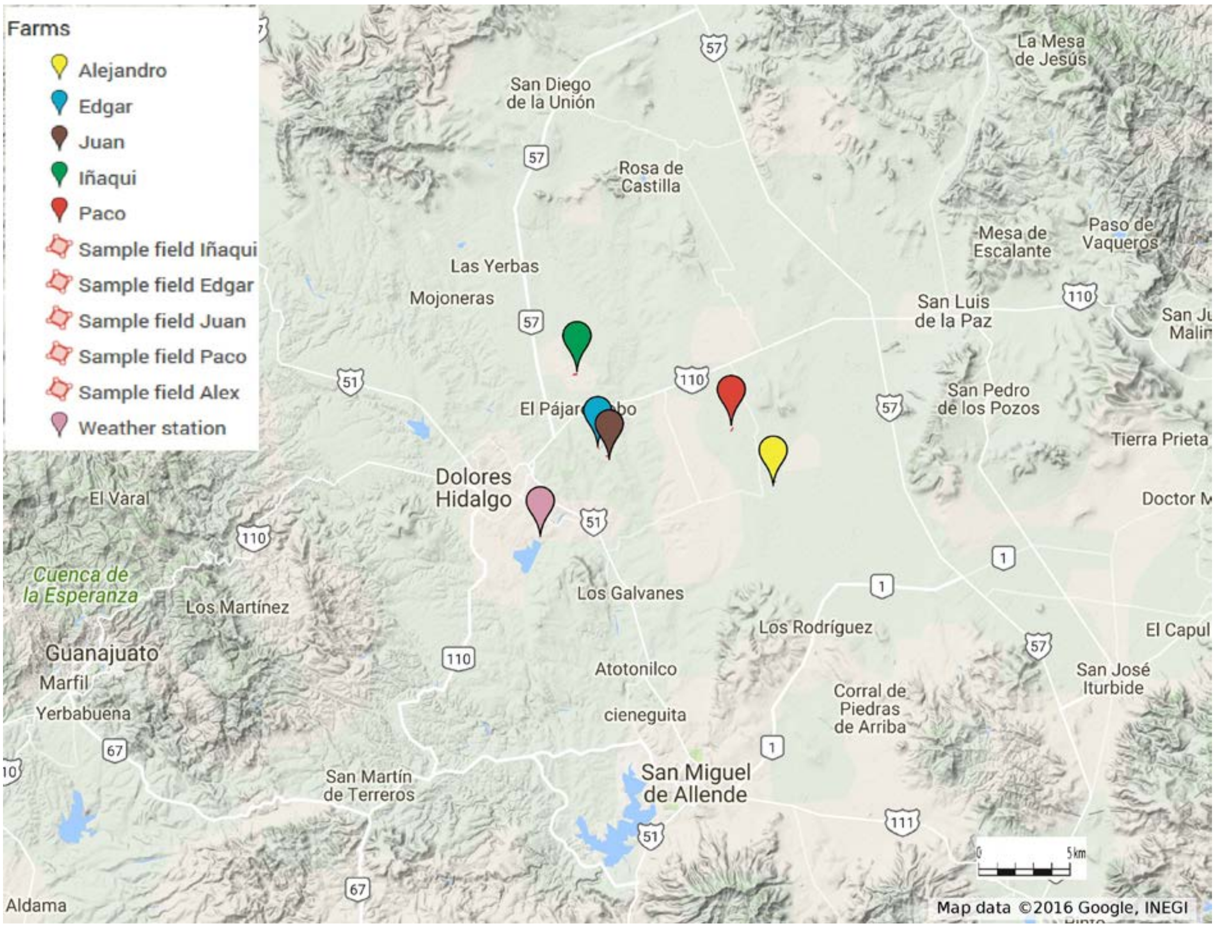
The values needed for the Cropwat calculations were derived using the **SPAW** Hydrology and Water Budgeting program (http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national//?&cid=stelprdb1045331)

2.3.5. Crop pattern: input of a cropping pattern for scheme supply calculations

The crop pattern was not relevant, since all the farmers had planted broccoli before the current crop (which is also broccoli) and will produce broccoli afterwards as well. Also, all the farmers fill up the soil to field capacity before they start a new irrigation cycle, which means that the amount of moisture that is still in the soil is not relevant.

3. The context of drip irrigation and state control in Guanajuato

Following the latest reform of the water laws, CNA is in charge of the concessioning of water rights in Mexico. In the concessioning period, farmers could basically claim any amount of water they considered appropriate (Reis, 2014). Most of the farmers were granted a concession of 6000 m^3 per annum. These concessions were given for a time span of between 5 and 50 years (LAN, 1992, Art. 24). The same law specifies that users are obligated to install volumetric flow meters that enable them to report their extractions to the CNA half-yearly. Despite the new laws, illegal pumps are still being installed (Hoogesteger, 2004). Officers of the CNA report that the volumes used by far exceed the concessions. (Reis, 2014, Scott et al., 2003).



Map 2 Research areas close to Dolores Hidalgo, maps. google.com

In conclusion, it can be said that water users are by far exceeding their concessioned volumes without having to fear consequences from state control. Three main points of critique for the failure of the CNA to control water resources were initially identified (Orthuizen, 1995), and were later increased to 6 (Hoogesteger, 2004):

1.State bureaucracies are hierarchical and centralistic

Within the CNA, planning is usually top down, follows standard administrative procedures and is centrally monitored through extensive hierarchical controls. Staff performance tends to be based not on output, but on conformity to higher authorities regarding the use of input. Consequently, management behaviour is too constrained and top-down to be able to deal effectively with dynamic field conditions. Guanajuato has one central CNA office of, from which all operations and controls are executed.

2.Lack of personnel at field level to exercise control

The regional office of Guanajuato has two groundwater inspection- and control teams for almost 18.000 wells (Sandoval interview 09-05-03). It would take the inspection teams 44 years to check all the wells in the state
Rent-seeking in a bureaucracy seems to be a worldwide phenomenon.
Nuijten (2003) gives a very good description of how bribes are a common way of getting things done when dealing with bureaucracy.

3.Bureaucracies are often subject to political influences

4. The lack of legal power of the CNA to control extractions
Although CNA officially regulates the exploitation of water, it has few legal means to reinforce it. CNA does not have the faculty to close irregular wells. The only way in which CNA can close a well is if another water user denounces an illegal well by means of queja (complaint) in which it is proven that the water supply of his own well is reduced by the other well.
Legally, all water users with a concession have to report extracted water volumes to CNA twice a year. This is impossible for most users, as the majority of the wells lack flow meters. (although legally they are required and sanctions are possible if they are not installed (LAN, 1992)). Furthermore, fines for the overexploitation of water are low

compared with the revenues users get from trespassing the law. Thus, for farmers there are few incentives to play by the rules.

5.Impunity

Rent-seeking is only possible in a widespread manner in a system where impunity prevails, and where users and functionaries are not punished for irregularities. Nevertheless, impunity, just as rent-seeking is part of a culture in which people do not interfere with other peoples' business as they do not want others to interfere with their own. This is part of cultural ethics.

6.Electricity subsidies in Mexico also encourage consuming energy for pumping. Agricultural consumers pay the lowest price of all consumers in Mexico for the power they need to pump up the water (Komives, 2009). Electricity prices are set by the CFE, and vary for the different months of the year. Farmers pay between 30,46 and 32,44 MEX-$ for each KWh. (CFE, 2015)

Sector	Sales (GWh)	Subsidies (2006 MM Pesos)	Price/Cost Ratios
Residential	44.5	63,369	.41
Commercial	13.2	5,476	.92
Agriculture	8.0	9,211	.30

(Komives et al., 2009), Average electricity prices for different consumers in Mexico (2006)

4. Results: Farmers interviews and observations

It is striking how homogenous the group of farmers that were interviewed was in their motivation. All of them are male, the land that they work on is mainly owned by their families, and all of them are closely connected to each other. They often meet for dinner and lunch, and discuss current events and farming strategies, prices and markets. Some of the farmers are even distantly related. All farmers have the same concession, which is $6000m^3$ per annum. Open basins for the storage of the water can be found on all farms. All farmers employ at least 2 riegadores (Paco has 3), meaning farm workers that operate and maintain the irrigation systems. Farmers hardly get out of their vehicles to inspect the fields or the irrigation system in detail. Their job resembles the position of a supervisor; their main objective is to make sure that their employees do the actual field work. This is usually done by having really brief conversations while hardly stopping the car. All riegadores have a needle, which varies a lot in size. If they find that emitters are plugged, they either try to carefully unplug them or punch in a new hole. Drip lines are flushed whenever the riegadores feel it is necessary. Only the drip lines that are at the hydrological end of the system are flushed regularly, since it is consensus between the riegadores, that the other drip lines need no flushing None of the riegadores has a formal education or training. Knowledge is passed on between the workers, the farmers do not train their riegadores.

4.1. JUAN

Map 3 Sample field Juan, Maps.google.com

This farm has used drip irrigation since 2000. The main motivation to shift from furrow to drip irrigation was the savings in labour. Since farmers are not willing to pay high wages, and the car industry was booming in Guanajuato in the mid-1990s, it was hard for farmers to maintain a sufficient workforce. It became clear, that they needed a new irrigation system which could also carry out other agricultural tasks. This was the reason why they invested in a large-scale irrigation system. This system also allows them to apply most of the fertilizers required for their typical crops. Water saving was of little concern when the system was planned. In 2014, they adopted a new irrigation schedule, which applies more water in a shorter time to minimize evaporation. The saving is achieved by a 20-day break one week after planting the new crops. Since the systems are mostly underground, it is hard to quantify conveyance losses. There certainly are some around the manifolds and cross-sections, but they are of no concern to the farmers. Irrigation schedules are designed by technical consultants. They are instructed by farmers to reduce the overall costs, which means that labour and fertilizers are reduced, while a reduction in water consumption is not relevant. Traditionally, several vegetables are grown on the farm. The most common are broccoli, onions, garlic and chillies. Which crop is grown is mainly defined by prices and marketing opportunities. Water requirements of certain crops do not affect the choice.

Since the swap to drip irrigation was already made 16 years ago, Juan and his father could not remember the consumption of furrow irrigation. They still emphasized that high water consumption did not play a significant role in their motivation to change to drip irrigation.

The switch to drip irrigation enabled them to operate all irrigation systems on the farm, which is approximately 150 hectares, with only two riegadores and one foreman. The system operators are untrained and unskilled, and get direct orders from the foreman. Their most important asset is their experience, which also influences most of their irrigation decisions.

One irrigation period lasts for approximately 80 days. Depending on the weather and the development of the crops, the irrigation period might be extended for an additional 10 days. If the temperatures are extremely high, there will be additional irrigation. Crops are grown throughout the year, but irrigation is only necessary between the beginning of October and the end of April. The summer crop cycles might be a bit longer, depending on the natural rainfall that occurs within the cycle.

If there is unforeseen rainfall, farmers will usually just skip or postpone one irrigation turn. This can lead to a stop in irrigation for up to two weeks. Often, irrigation turns are carried out, even if not necessary in terms of water delivery, to apply fertilizers.

The irrigation turns last for different periods, from only 2 hours at the beginning of the crop cycle up to more than 7 hours before harvest.

The farm has an excellent and detailed soil analysis for all the soils, which are heterogeneous. Nevertheless, the irrigation schedule is the same for all the fields, ignoring different topography or soil types. Different plants do have different schedules.

It is also typical that fields can only be split in half in terms of irrigation. It is therefore not possible to, for example, only irrigate the last quarter or the first quarter of the field without irrigating at least half of the area. The situation with fertigation is similar.

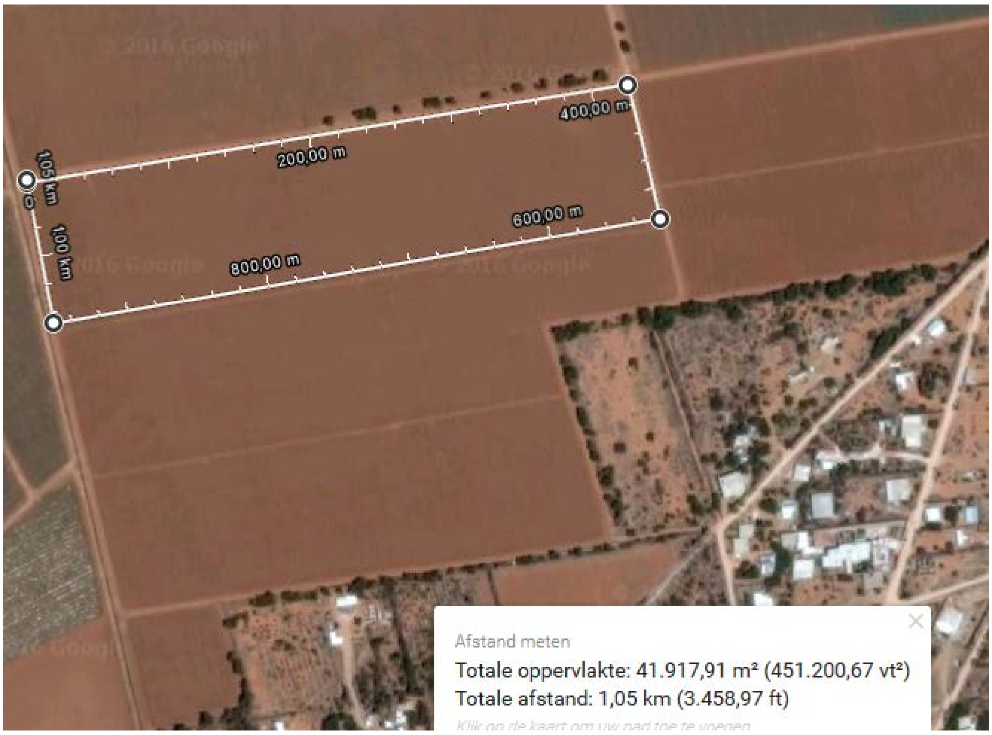
Fertigation schedules are set up by technical consultants from "Nutriland" and other fertilizer companies.

Since water saving is not very important to the farmers and the operators of the system, there is no control mechanism to prevent over-irrigation. On the contrary, foremen and operators stated that they always try to over-irrigate a bit, to avoid putting stress on the plants. They try to always store at least 10% more irrigation than scheduled, to ensure optimal plant growth.

The farmers on this farm are highly satisfied with the performance of their system, since economic revenue is their sole criteria for their success For them, the possibilities for marketing their crops is most influential factor in production patterns.
Also, Juan estimates the cost of irrigation to be only 12%. He thinks that the benefits from an increase in irrigation efficiency are probably not worth the investment.
Juan was one of the few farmers who said that he does not think that the ground water resources will be sufficient for him to sustain farming on the family land for the rest of his life. This might also be why he studied economics, to have an alternative source of income.
Nevertheless, he stated that there is no real point in water saving as long as the other users in the aquifer area are not prepared to restrict their use.

The sample plot was 3 ha, according to Juan. A quick measurement using google maps showed that the plot had an actual size of around 3,7 hectares.

4.2. IÑAQUI



Map 4 Sample field Iñaqui

Iñaqui recently invested in a state of the art irrigation system that is fully automatized and can be operated independently by a central computer.

Before the installation of the current system, he was using a drip irrigation system that was run manually.

Despite the possibility to run the system fully automated, most tasks are still carried out manually.

While the first shift to drip irrigation was mainly motivated by a desire to save water and labour costs, the second was intended to save fertilizers and allow for a more precise application of water, fertilizers and pest control. The most recent system allows to distribute the water over three different sections, which can be used separately. Since Iñaqui is the first farmer in the region with such a modern system, he can be considered an innovator. So far there are no farmers who copied his concept and decisions.

Fertigation played a central role in the decision to switch to the fully automated system. Iñaqui considers fertilizers to be the most expensive input for the production of broccoli. Since his soil is sandy, and not rich in nutrients, there is a necessity for artificial fertigation.

His decisions on when to start the irrigation is still defined by his own experience and the experience of the system operators.

Due to the fact that the system is very new and well maintained, there are very low conveyance losses. No one on the farm thinks that these are problematic.

Materials are like the ones used on the other farms. Big PVC-pipes are installed underground, while the water distribution on the field is done by drip lines, which must be renewed every 3 to 5 months. This farm is the only one that has a pressure compensator, which allows a very even distribution of water over the plots.

The installation of the system was roughly two times more expensive than a normal system. The system was made in Iran and was installed by the technicians of the firms involved. Maintenance costs are relatively high, since the owners rely on external technicians to operate and calibrate the system and to set up irrigation and fertigation schedules. This is done even though most irrigation turns are started manually by the operators.

Iñaqui's decisions in crop choice are only influenced by the prices he can achieve for them. Since he estimates his irrigation costs to be roughly 20% of his total costs (this is the highest estimate of all the farmers), he is still not interested in minimizing water consumption.

Like the other farmers, Iñaqui was reluctant to make statements about exactly how high his pumping costs are. Like the other farmers, he is concerned about the dropping ground water levels, since his pumps have already reached their capacity. If the decrease continues, he will be forced to invest in a new pumping system.

As mentioned above, the water requirements of a certain crop are not relevant to the farmers compared to other production factors such as fertilizers and pesticides.

Since the switch from furrow to drip irrigation occurred more than 20 years ago, none of the farmers can say what percentage of water they save by using the new system. For Iñaqui, the main motivation to shift to the even more modern system was that it can deliver pesticides and fertilizers more accurately to the relevant parts of the fields.

One of his main arguments as to why he invested in the new system was that he only needs two operators to run the system. The task of these men is to clean and maintain the system, and turn the water supply on and off, when this is not done automatically (which is hardly the case). Both operators are not formally trained, but rely on experience to do their job. Their main tasks are to unclog the drippers in a careful manner with a small needle and to reconnect hoses that have become detached from the manifold.

Irrigation periods vary a lot, starting at 2 to 3 hours a day at the beginning of the crop cycle to up to 8 hours just before harvest. One crop cycle typically lasts 80 days, depending on the weather conditions, it can be extended for up to 10 days. The first irrigated crop cycle starts around November, the last around March.

Despite the fact that there is a different precipitation and climate condition in the first and second crop cycle, the irrigation schedules remain the same.

The irrigation schedule is the same, despite there being different soils on the farm. However, fertigation and pesticides are again adapted to the specific requirements of each plot.

Usually, the water is stopped when the operators think that the amount applied is sufficient. Typically, they tend to over-irrigate, since they want to make sure that there is no shortage of water at any time. Due to this thinking, there is not only no control mechanism against over-irrigation, but even intentional over-irrigation.

As on the other farms, the system operators have no formal training. They are instructed by the foremen or the farmers, and do their job based entirely on their personal experience. The attitude towards water use has not changed since the new system was

installed. The operators are happy because more of their work is now done by automatization.
The savings of drip irrigation versus furrow irrigation was not known to Iñaqui. His farms have used drip irrigation for over 20 years, and furrow irrigation is not relevant to him.
Extreme weather events are not very frequent in the area, according to Iñaqui. Most common are cold nights, which pose a threat to the farmers, because the newly planted seedlings are prone to freezing. In the case of extreme rainfall, farmers usually skip one or two irrigation turns, and subsequently return to the regular schedule.
Iñaqui stated that the sample plot was about 3 hectares. The plan he presented earlier showed that the plot has around 4,4 hectares. Satellite image measurements result in roughly 4,2 hectares for the sample plot.

4.3. PACO

Paco is the manager of several farms in the area. He owns some of them, but also manages farms for other people. He studied international accounting, but is still in charge of the important decisions made at the farm. He employs a forewoman, Maira, who manages the everyday business on the farm. The interview was conducted in his car, while he was checking on the progress on his farms. He does not visit the farms every day, since he is busy with the marketing and selling of the crops. Part of his farm is also a packaging unit for broccoli. He does not only sell his own crops, but also those of other farmers in the region.
When Paco started working in agriculture, all the farms had already switched to drip irrigation. He is not overly concerned with the technicalities of broccoli production. He has developed an own irrigation schedule together with his brother, who studied agronomy. He does have a fertigation system installed, and is using it in his production process. He likes fertigation, because it saves labour costs, and it can also substitute manual labour, which depends on the reliability of the workers.

Paco is only producing broccoli in different growth stages on the main farm. Broccoli is grown throughout the year, and as soon as the operators think that the soil is dry, they start the system and apply water.

The maintenance of the system is not greatly important to Paco. Drip lines are replaced every 5 to 7 years, instead of every 3 t o5. Also, the system operators use nails the size of a small pencil to punch open the drippers when they are clogged. This leads to excessive emission of irrigation water on some parts of the fields.

Paco uses cheap materials, speaking of a standard drip installation with big underground plastic tubes and plastic drip lines.

The maintenance costs are very low, since Paco waits longer than recommended to change and maintain the drip lines.

Paco does not know how much he pays to pump up the water. The electricity costs vary a lot, which leads to different costs for the pumping.

Since only broccoli is grown on the farm, different CWR are not relevant for Paco. The CWR can still vary, because depending on the market where he intends to sell his crops (Japan or USA), broccoli are planted closer to each other or further apart to achieve the required size for each market. The irrigation schedule is not affected by this agricultural decision.

When Paco started working on the farm, drip irrigation was already in place. Therefore, he does not know if there was a saving in furrow compared to drip. For him, it is more interesting that he was able to expand his production, due to a reduction of manual labour. Labour costs were drastically reduced through the introduction of drip irrigation. This is due to the fertigation and the lower maintenance requirements of drip irrigation.

Paco now relies on three system operators. One of them (Mauricio) is the foreman of the other two. None of them have a formal training, and all of them only received a basic school education. Mauricio has been doing the job as an irrigation operator for 8 years. He started as a farmhand, and was trained by the former irrigation staff. He relies on experience, and all daily decisions are made by him. He does not keep a written record of the schedule, nor of the irrigation that is carried out over the year.

Irrigation periods are usually 80 to 90 days. Paco's system is relatively simple. For the first 40 days, he applies 3 and a half hours of irrigation every two days, for the second part of the growth cycle he applies 7 hours. Paco stated that he tries to create a humid micro climate by irrigating excessive water which evaporates in the sun.

If there are extreme rainfalls, operators will possibly skip one irrigation turn. The pumps are always running, meaning that there is irrigation all the time during the irrigation period. Irrigation sessions are not adapted to different environmental conditions. The irrigation is the same on all the farms managed by Paco. Since only broccoli is grown, water requirements remain constant during the whole irrigation period.

When asked, Paco and the operators stated that they over irrigate on purpose to avoid any possible water stress to the plants. They are aware that the system has a poor distribution uniformity performance and compensate for that by prolonging the irrigation turn by 10 to 15%. Between July and October Paco applies 50% less water, since there is more rainfall.

The awareness of the poor uniformity does not mean that the operators are unsatisfied with the system. They do not consider it to be a problem, since water is cheap compared to other production inputs.

Due to the usage of oversized needles especially at the end part of the system, there is excessive water loss through the affected drippers.

4..4. EDGAR

Map 5 Sample field Edgar

Edgar works on his farm together with his family. He, his father and his brother oversee the management of the farm. Edgar studied agronomy, as did his father. His father remembers that he switched to drip irrigation because there was a labour shortage at the mid-1990s. He stated that the car industry expanded now in the region, and people preferred to work in the factories instead of on the fields. Today, they still have problems finding sufficient workers for the peak seasons in agriculture.

Drip irrigation was supposed to minimize the manual labour input in agricultural production. Now, only two system operators can run and maintain all irrigation tasks. Edgar's work consists of driving around, supervising and talking to his employees, mostly without getting out of his vehicle. He is also a horse-riding enthusiast, a hobby to which he devotes a lot of his time. His interest in horses exceeds his interest in irrigation techniques. Following an accident, he has problems breathing through his nose, which also makes it hard for him to do physical work for a prolonged time.

Edgar is an old school and university friend of Alejandro. They and other farmers of the area meet almost daily to discuss recent events and their agricultural decisions. Still, Edgar has developed the most sophisticated irrigation schedule. He also has a different schedule for the different crops that he cultivates on his land (broccoli, chillies).

Edgar uses fertigation on his farms. When he designed the current irrigation schedule, his most important goal was to optimize the fertigation. He applies a fertigation mix that has been designed by the consultants of Nutriland, a local fertilizer company, for him. Water savings were not relevant for the design of the fertigation/irrigation schedule. Irrigation is typically started as soon as the natural rainfalls get more scarce at the beginning of November. The second crop cycle is typically started in January. This is always a risky game, because the farmer with the earliest harvest can market his crops for the highest prices. Since the nights are very cold in January, the freshly planted seeds are at risk of freezing damage, which usually means that the labour-intensive planting has to be repeated to replace the frozen plants.

Conveyance losses are not of big concern to the farmers. Almost all the big manifolds and pipe connections are leaking.

Edgar uses a standard drip design that was built 20 years ago. The design is very similar to the ones on the neighbouring farms.

Edgar stated that the installation of the whole system cost about 250.000 pesos per hectare. This estimate, which is more than 10 times the real costs, demonstrates his lack of knowledge about financial matters on the farm. An interview with the local drip installation company showed that installation costs of such a system are about 2100 US-$ per hectare.

Maintenance costs depend highly on how often farmers change the drip lines. Also, all materials must be paid for in US$, which means that the price of maintenance is highly dependent on currency exchange fluctuations.

As mentioned above, pumping up the water is subsidized by the government. Despite this, Edgar complains about the high pumping costs. He has three pumps on his property, but one of them is not working, because the water level is too low for the pump to reach. Within the irrigation period, pumping costs amount to roughly 800 US-$ a month, sometimes even more, depending on the price for electricity.

Edgar grows chillies, broccoli and grassland (fodder). The choice of broccoli or chillies is mainly influenced by the prices for the respective products. He also cultivates small chilli plants from seed himself, and the development of the seedlings also influences the crop choice. Small chillies are less cold-tolerant than broccoli.

Edgar uses a different irrigation schedule for chillies and broccoli. Still, the different CWR do not influence his decision on what crop he decides to grow.

Edgars family has used drip irrigation since 1995. For them, it was most important to reduce the amount of manual labour required for the daily operation of the farm. They cannot say how much water they saved by switching to drip irrigation, but Edgar is sure that, combined with the lower required labour input, drip irrigation was an excellent investment.

Edgar said that it is extremely difficult to find workers at all, since most of them prefer to work indoors. Also, the car industry pays more than Edgar, meaning that there are times where he cannot find enough workers.

Edgar has two system operators who run the system on a day-to-day basis. Both have only elementary school as a formal education. They started working as farmhands in agriculture, and rely entirely on their experience.

Edgar has a big blackboard with the irrigation instructions written on it in the main pumping house. Irrigators go there for the daily irrigation and fertigation tasks. One irrigation period is about 80 days. If there is very little sunshine or some other factor that inhibits the plant growth, it is extended for roughly 10 days.

Edgar and his family stated that they are satisfied with the performance of their system. The only thing that bothered them was that their electricity bills kept increasing, due to dropping water levels. Edgar improved the irrigation schedule, and he also taught his operators how to use the needles in order not to create excessively big drip holes in the drip lines. He does not use pressure meters, since his operators feel the pressure by touching the drip lines.

His two irrigation operators are maintaining and operating the irrigation system as a full-time job. Both regularly flush the ends of the drip lines, unclog clogged drippers and regulate water pressure. They stated that they prefer to over-irrigate by roughly 10% in order to prevent stress to the plants.

In case of extreme rainfall, usually one irrigation turn is skipped, after which irrigation continues as usual.

Edgar stated that the sample plot has 3 hectares, while satellite image measurements show that the plot is around 2,6 hectares.

4.5. ALEJANDRO

Alejandro is an engineer at COTAS in Dolores Hidalgo. He also owns land close to Paco's ranch. He went to university and studied agricultural engineering. He lives in Dolores, together with his family. He is also an old school friend of Edgar.

Since Alejandro is mostly busy with his full-time job at COTAS, Paco manages everyday business at his property. The drip irrigation system was installed before Alejandro got the land, which means that he was not involved in the decision to switch from furrow to drip.

Since Alexandro's farm is managed by Paco, his irrigation schedule is exactly the same as Paco's.

Alejandro's system is equipped for fertigation, and he thinks that this is the most important aspect of his system.

Irrigation starts as soon as the farmers feel that their newly planted broccoli is not getting enough water. Since Alejandro is an agricultural engineer, and he and Paco have a lot of experience and know the area and the soil, they do not rely on external opinions on when to start irrigation.

Alejandro is not concerned about irrigation losses, since the basin is in a central position. Also, his system has been modernized, meaning that the tubes have been renewed. Alejandro changes his drip lines every 3 to 4 years. The operators told me that the drip lines got damaged while rolling them up last year, which means that they will be replaced the following year.

Alejandro stated that his system installation cost around 50.000 mex-$ per hectare. Irrigation and the maintenance costs of the system amount to 2454 mex-$, according to his books. Electricity for the pumps costs around 2000 mex-$ for one irrigation cycle.

Alejandro told us that all the farmers have a concession for 6000 m^3 of water per hectare.

Alejandro uses standard drip lines which are cleaned and maintained by the operators. The operators use a fine needle, and carefully clean the drippers.

Since Alejandro grows only broccoli, different CWR are not relevant to him. His crop choices are influenced by Paco, who also organizes the sale and marketing of the crops.

Alejandro was not involved in professional agriculture at the time that the irrigation switched from furrow to drip. For this reason, he does not know if there are water savings, and if so, how they accumulate. However, since Alejandro believes that irrigation amounts to a maximum of 10% of his total investment costs, he does not feel any incentive to investigate this.

Like all the farmers in the region, Alejandro did have problems to find sufficient labour. Drip irrigation combined with fertigation does save a lot of manual labour, since it requires only two permanent workers on his property.

These two operators have no formal education. The interviews were difficult, because the operators were under the impression that they were supposed to learn from this, and were reluctant to give away information. Nevertheless, they stated that they grew up working on farms, and that they rely on their experience and the instructions of Alejandro to operate the system. They also stated that they over irrigate on purpose, since their highest objective is to avoid drought stress to the plants.

One crop cycle lasts typically 90 days. The irrigation schedule is only different for the first 45 days and the last days. Before plantation the field is filled to maximum capacity, and there is no irrigation for 8 days after plantation.

The irrigation plan is not adapted to geographical or other conditions. If there is more rain, irrigation is postponed until Alejandro thinks that the soil is not moist enough anymore. This depends on the growth stage of the broccoli, and will be no more than 15 days. Normally his irrigation accumulates to 135 hours in total for one crop cycle.

Figure 2- Typical repair for a broken lateral

Since the operators purposefully over-irrigate, no control mechanism is necessary. The operators are not satisfied with the condition of the drip lines, since they are quite old, but Alejandro is satisfied with the overall performance and output of his farm. This also has to do with a strong US$ and a relatively weak Mexican peso, making exporting goods from Mexico to the US more profitable for domestic producers.

The main changes to the system are that there are several drip lines connected to one outlet of the lateral. This happens when one of the connection between the laterals and the drip lines break. They are typically repaired when there is enough time and the system is not working. This means that some of the broken connection components will not be replaced until the wet season.

Everyday business is carried out by the operators. They work mostly independently; Paco or Alejandro check on them when they have time. The irrigators' credo is that they try to avoid drought stress to the plants at all costs. This means that they will turn on the irrigation system as soon as they have the impression that the plants look "thirsty". As mentioned above, extreme rainfalls will postpone irrigation for up to 15 days, depending on the amount of rain.

5. Results: CROPWAT Calculations

5.1. Current irrigation patterns run with CROPWAT

During the first field observations, it became clear that the uniformity and condition of the systems are not fit to meet the efficiency standards to 90 - 95%.

Distribution uniformity was quite low (between 0.31 and 0.58), which also indicates a poor system performance.

The key indicators within the calculations are the gross amount of irrigation water applied, the actual irrigation requirement and the yield reduction. It is important to bear in mind that farmers only possess water rights for a groundwater abstraction of 600mm per annum.

All the farmers exceed this limit. Considering that fertigation is also used to apply agricultural agents on the fields during the wetter seasons it becomes obvious that the regulations for water abstraction are being ignored entirely.

As could be expected, the farmer with the most detailed irrigation schedule (Edgar), also applies the smallest amount of water. Some of the farmers suffer from yield reductions during the second growth cycle.

Farmer's name	Gross irrigation (mm) supplied by farmers	Actual irrigation requirement (mm) According to CROPWAT	Surplus (mm)	Surplus factor	Yield reduction in %	DU
Alejandro and Paco						0.4 (Alejandro) 0.31 (Paco)
1st cycle	612	244	368	2.5	0	
2nd cycle	612	440	172	1.4	0	
Juan						0.5
1st cycle	578	246	314	2.3	0	
2nd cycle	578	440	138	1.3	15	
Iñaqui						0.45
1st cycle	501	244	257	2.1	0	
2nd cycle	501	244	257	2.1	6	
Edgar						0.57
1st cycle	344	246	98	1.4	8	
2nd cycle	347	440	-93	0.8	27	

Table 1: Selected values from CROPWAT

Distribution uniformities were calculated using the indicated method. None of the farmers reached a satisfying drip uniformity. This is mostly due to the fact that there are a lot of completely clogged drippers at the hydrological end of the system.

5.2. Irrigation by CROPWAT

The theoretical irrigation runs were computed using Cropwat. Since all the farms are assessed by the same weather station, the irrigation recommendation is the same for all the farms. The irrigation applications were computed on a basis of one irrigation session every second day. This prevents excessive labour costs for a 24-hour operation of the system by the riegadores. The soil is filled up to field capacity every second day. The first potential planting date was September 20th, the second was January 20th. Variations of these planting dates only have a marginal impact on the results.
Irrigation efficiency was projected to be 70%. This is optimistic, since distribution uniformities vary by around 50%. The basis for this estimate is the idea that, since there is a massive over irrigation, water will disperse and reach other crops as well. Also, the last few meters of every drip line are often either completely blocked or punctured wide open. The excessive water does sometimes also reach otherwise completely dry spots.
The gross irrigation application for the first irrigation period would be 387,6 mm, assuming an irrigation efficiency of 70%. The second irrigation period, which is characterized by higher temperatures and less rainfall leads to a gross irrigation application of 594,9 mm. This adds up to a gross irrigation application of 982,5 mm, assuming an irrigation efficiency of 70% and irrigating up to field capacity every second day.

Another possibility would be to irrigate only at the point of critical depletion. This would lead to a gross application of 285,7 mm for the first irrigation period and a consumption of 514,3 mm for the second period. This amounts to a total gross irrigation application of 800 mm per annum.
This only includes two cropping cycles. As mentioned earlier, all the farmers produce three cycles per year. The third cycle does not require as much irrigation as the other two, since it takes place during the wet season, but occasionally farmers will still turn on their system to apply fertilizers.

6. Discussion and Conclusion

6.1. Shortcomings of the CROPWAT software

The software CROPWAT, that was used to determine and calculate irrigation schedules, was originally designed for surface and furrow irrigation. This means that adjustments need to be done to use it for drip irrigation applications.

Furrow and surface irrigation usually have fewer irrigation turns, meaning that it is sometimes necessary to create averages, in order to be able to enter all the relevant irrigation turns for the current irrigation.

The estimate of the irrigation efficiency of 70% is probably most prone to error. This is because it was impossible to measure real efficiency for this thesis. Using reference literature is highly problematic, since it cannot be determined how comparable the different research sites are. If anything, the estimate of 70% is too optimistic, which only emphasizes the main conclusion of this thesis, that drip irrigation is not being used as a water saving tool.

Furthermore, the weather station is not in a central position. This means that there is a distance of roughly 8 kilometres between the weather station and the most distant farm.

The distribution uniformity calculations included drippers which did not emit at all. The fact that there are several completely plugged emitters confirms that the systems are not maintained adequately. It is important to emphasize that distribution uniformity and irrigation efficiency are two different terms. Since systematic over irrigation is taking place, distribution uniformity is not the first priority for the survival of the plants.

Since it was not possible to measure irrigation efficiency with the time and resources available for this research, pressure variations and distribution uniformity are used to indicate the performance of the system. Even if the DU values are acceptable, the efficiency of the system will still be low due to intentional over irrigation.

Another crucial point is, that the kc values used were not adjusted for partial wetting and the specific location. This emphasises, that the derived numbers are good for an indication, but nowhere close to a precise result.

The table below presents irrigation schedules that are within the legal water consumption, and would enable farmers to produce two crop cycles during the dry season. If the condition of the irrigation equipment is poor, yield reductions are possible.

Farmer's name	Current irrigation requirement (mm) according to CROPWAT	Yield reduction in %
Alejandro and Paco		
1st cycle	245	0
2nd cycle	440	0
Juan		
1st cycle	246	0
2nd cycle	440	15
Iñaqui		
1st cycle	244	0
2nd cycle	244	6
Edgar		
1st cycle	246	8
2nd cycle	440	27

Table 2: Selected values from CROPWAT

The figures presented above are the result of several measurements and calculations, which must be discussed in order to show potential flaws and sources for inaccuracies before talking about the results.

6.2. General Discussion and Conclusion

As expected, the results show that drip irrigation is not being used as a water saving tool. Instead all the farmers stated that they use it in order to reduce manual labour on their farm. Their irrigation schedules, which are designed to meet fertigation requirements and not CWR support this conclusion. It is fairly easy to build an argument out of the observations, measurements and the interviews.

It is interesting to look at the different domains in which the farmers are living in this context.

In the human agency domain, it became obvious during the discussion that the farmers' main rationale is to reduce manual labour and not to save water. This rationale is passed on to the operators, who even increase the water consumption, just to be sure to reach a level where there is zero water stress. This rationale can be clearly found by looking at the use of their resources. The land use is maxed out, the use of chemical inputs is abundant, but manual labour is reduced wherever possible. This surely is caused by both internal factors and external factors like the cheap peso and the high demand for fresh vegetables in the US and Japan. Farmers therefore develop their rules and routines based on these three factors. Social gatherings are important for exchanging information, which also means that farmers are likely to follow similar goals and rationales, since there is no major input from individuals outside of their own rationale. Farmers constantly asked me how much the other farmers were pumping, and what I think about their irrigation practices, which shows that it is of interest to them what their neighbours are doing.

Farmers are not interested in saving water, even if they realize that the water levels are dropping drastically. Their main argument against water saving is the lack of control and that if they don't take it, their neighbour will.

It stood out how all the farmers had the same motivation and rationales concerning their irrigation practices. None of them were interested in actual water savings. All of them considered fertigation and a reduction in manual labour the most important benefits of drip irrigation. All farmers relied on technical consultants, mainly from Nutriland, to calculate their fertigation needs. Since businesses are interested in selling products, it is likely, that these consultants tend to favour selling as much fertilizer as possible over saving water for their clients, therefore increasing the water consumption on the fields.

It was surprising to see that farmers do not know the actual size of their fields. In three cases, it was possible to use satellite measurements to see the differences between the actual plot size and what the farmers believed the plot size was. It is clear, that it is not possible to calculate exact CWR and irrigation schedules without even knowing the size of a plot. Also, this demonstrates the lack of interest for good practices, since it is easy to access this information and all farmers had the technology to do so.

Distribution uniformities are surprisingly low and homogenous. This is not surprising, but more a logical consequence considering the maintenance that is carried out on the field.

Another problem that emerged during the interviews with the riegadores was that they were reluctant to give information. They are aware that they can be easily replaced, which made it very hard to have a conversation. It is likely that they were under the impression that they were being tested and evaluated. It took several interviews for them to open up and share information about their irrigation practices.

The calculations for the CROPWAT computed irrigation have shown that in both cases, and even assuming an irrigation efficiency of 70% (which is quite optimistic), it is not possible to grow two cycles of irrigated broccoli in the designated periods without exceeding the legal concession limits. Filling up the field every second day results in a gross irrigation demand of 982.5 mm, while filling up the field at the point of critical depletion leads to a gross consumption of 800 mm. Since the legal limit is 600 mm, farmers have to either reduce their production or tolerate massive yield reductions due to drought stress.

Despite their excessive water application some farmers still suffer from yield reductions due to water stress. This could be avoided by different irrigation schedules. Also it is likely that the riegadores just increase the water application if there is a hot couple of days. Still, farmers could avoid these reductions by elaborating their irrigation schedules towards giving more water in later development stages and hotter weeks.

The third cropping cycle, which takes place in the wet season, might even consume additional water, because of fertigation. The fact that water is used for this purpose, although it would be possible to just apply the fertilizer with manual or mechanical effort shows that water saving is of little interest compared to savings in manual or mechanical work. Nevertheless, since farmers could produce with around 245 mm of water for one cropping cycle during the dry seasons, this would still leave them 110m for the third cropping cycle during the wet season. This means, that three cropping cycles are possible with a concession of 600 mm of water, if the systems are in a decent condition.

Farmers are exceeding their water rights greatly and intentionally. Since all the farmers stated that fertigation was more important for them than water saving, it can be stated that drip irrigation is used as a labour-saving and not as a water-saving tool.

It is obvious that farmers need to reduce their production intensity if they wish to stay within the legal limits for water abstraction. Assuming that the government water concession plan is based on a sustainable hydrological plan, this means that farmers would need to skip one entire crop cycle per year. It is very unlikely that farmers would be willing to do this.

This leads to the conclusion that irrigation subsidies need to be changed and state control needs to be established to achieve substantial water saving in the region. If these steps are not implemented, water competition will become increasingly fierce, forcing more and more producers out of business.

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8. Annex I

Interview questions for the farmers:

Why do they use drip irrigation in the 1st place?
Are their irrigation decisions influenced by what other farmers are doing?
What role does fertigation play? Are they using it and if yes in what amounts?
What shapes their decisions on when to start the irrigation, how long the turns last and when they stop irrigating (irrigation software, technical advisors, experience, "intuition", own observations?)
How do they think about conveyance losses?
What materials are used and why?
How much did they pay for the installation of the system?
How high are the maintenance costs every year?
How much do they pay for pumping up the water for one irrigation period?
Does the CWR of a specific plant influence their choice in crops?
How much do they save in water using drip irrigation instead of furrow irrigation?
How did the drip irrigation system influence the labour costs on the farm?
Who is operating the systems on a daily basis?
What is the qualification of the system operators?
How long is one irrigation period?
How long is one crop cycle?
If there is more than one crop cycle, are the irrigation schedules adapted to the different weather?
How long does one turn last?
How is the irrigation plan adapted to local soils, topography and plants?
Is the cropping calendar adjusted to water requirements?
Is there a control mechanism that prevents over irrigation?
Are they satisfied with the way their system runs?
What changes have they made in the past to "improve" the system?
Who is operating the system? To what extend are they involved in irrigation decisions
Do they think that they are applying the right amount of water or are they aware of possible over irrigation?
How do they react to rainfall or extreme weather events?

9. Annex II

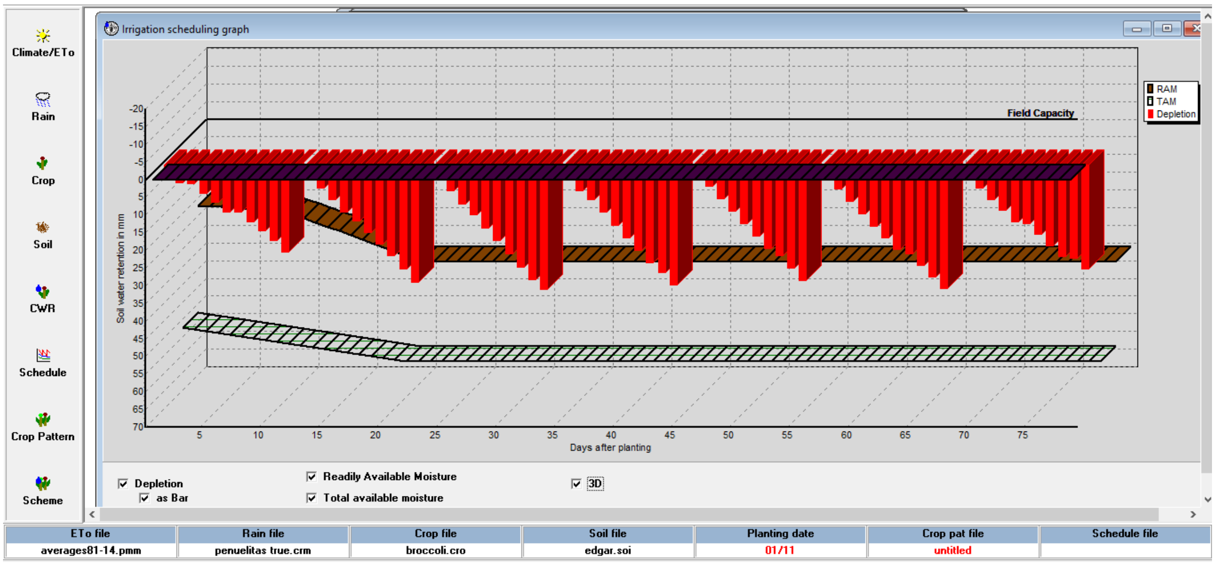
Table of contents

The following annexes present the difference between current irrigation patterns and the results from CROPWAT calculations.
Monthly averages were taken from daily weather data (ET_0) between 1981 and 2014.
For the calculation of the effective Rainfall the USDA soil conversation formula was used:

Peff = Pmon * (125 - 0.2 * Pmon) / 125 for Pmon <= 250 mm
Peff = 125 + 0.1 * Pmon for Pmon > 250 mm

Cropwat projects three development stages, Development (Deve), Middle (Mid) and Late (Late)

Juan: Current irrigation



Annex table 1: Current irrigation Juan

Weather data

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2
Average	5.0

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1

August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Crop Name: Broccoli
Planting date: 01/11
Harvest: 19/01

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Crop height (m)			0.40		

SOIL DATA

Soil name: ALEJO

General soil data:

Total available soil moisture (FC - WP)	100.0	mm/meter
Maximum rain infiltration rate	25	mm/day
Maximum rooting depth	120	centimetres
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	100.0	mm/meter

CROPPING PATTERN DATA

Cropping pattern name:

No.	Crop file	Crop name	Planting date	Harvest date	Area %
1	BROCCOLI.CRO	Broccoli	01/11	19/01	
2	BROCCOLI.CRO	Broccoli	22/02	12/05	

CROP WATER REQUIREMENTS

Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Deve	0.71	2.63	26.3	4.7	21.6
Nov	2	Deve	0.95	3.34	33.4	1.7	31.6
Nov	3	Mid	1.10	3.76	37.6	1.9	35.7
Dec	1	Mid	1.10	3.65	36.5	2.1	34.3
Dec	2	Mid	1.10	3.53	35.3	1.8	33.5
Dec	3	Late	1.08	3.51	38.6	2.8	35.7
Jan	1	Late	1.05	3.29	32.9	4.3	28.6
Jan	2	Late	1.02	3.16	28.4	4.8	23.1
					268.9	24.2	244.1

CROP IRRIGATION SCHEDULE

Planting date: 01/11
Soil: ALEJO Harvest date: 19/01

Yield red.: 4.1 %

Crop scheduling options
Timing: Irrigate at user defined intervals
Application: User defined application depths
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Nov	1	Init	0.0	1.00	100	5	21.0	0.0	18.4	30.0	3.47
7 Nov	7	Init	2.4	1.00	100	20	32.0	0.0	21.1	45.7	0.88
27 Nov	27	Mid	0.9	0.37	83	88	32.0	20.6	0.0	45.7	0.26
5 Dec	35	Mid	0.0	0.66	92	78	32.0	14.6	0.0	45.7	0.66
12 Dec	42	Mid	0.0	1.00	100	65	32.0	6.8	0.0	45.7	0.76
19 Dec	49	Mid	0.0	1.00	100	50	32.0	0.0	2.3	45.7	0.76
26 Dec	56	End	0.0	1.00	100	39	32.0	0.0	8.9	45.7	0.76
29 Dec	59	End	0.0	1.00	100	18	32.0	0.0	21.5	45.7	1.76
2 Jan	63	End	0.0	1.00	100	23	32.0	0.0	18.4	45.7	1.32
5 Jan	66	End	0.0	1.00	100	16	32.0	0.0	22.1	45.7	1.76
9 Jan	70	End	0.0	1.00	100	18	32.0	0.0	21.1	45.7	1.32
13 Jan	74	End	2.7	1.00	100	17	32.0	0.0	22.0	45.7	1.32
16 Jan	77	End	0.0	1.00	100	16	32.0	0.0	22.5	45.7	1.76
19 Jan	End	End	0.0	1.00	0	11					

Totals:

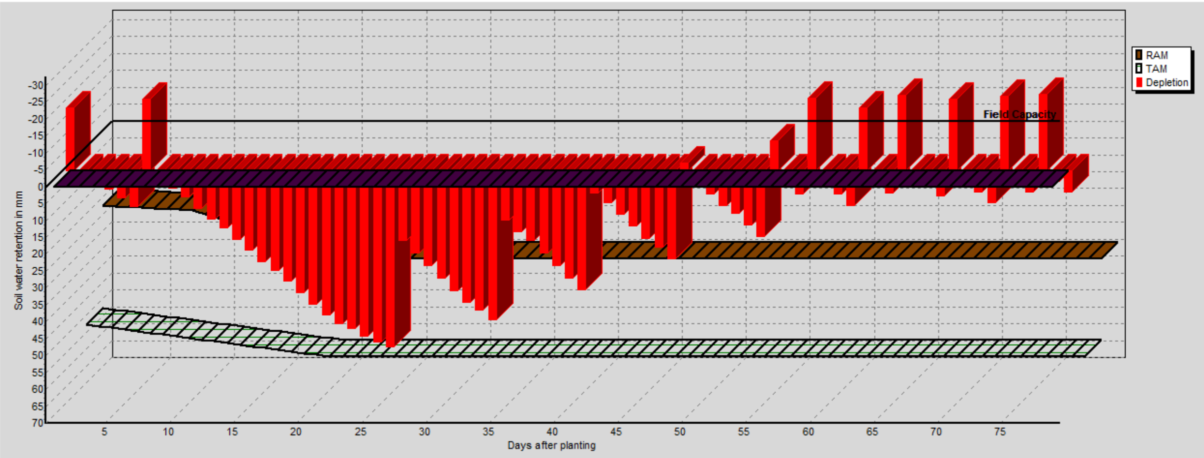
Total gross irrigation	578.6 mm
Total rainfall	25.2 mm
Total net irrigation	405.0 mm
Effective rainfall	18.8 mm
Total irrigation losses	178.2 mm
Total rain loss	6.4 mm

Actual water use by crop 251.9 mm
Moist deficit at harvest 6.3 mm
Potential water use by crop 265.7 mm
Actual irrigation requirement 246.9 mm

Efficiency irrigation schedule 56.0 %
Efficiency rain 74.6 % Deficiency irrigation schedule 5.2 %

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.1	12.6	0.0	5.2	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.1	11.9	0.0	4.1	%
Cumulative yield reduction	0.0	0.1	12.0	12.0		%



Annex table 2: Current irrigation Alejo

Second Crop Cycle February

Weather data:

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1

November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

Station: Penuelitas

Eff. rain method: USDA Soil Conservation Service formula:
Peff = Pmon * (125 - 0.2 * Pmon) / 125 for Pmon <= 250 mm
Peff = 125 + 0.1 * Pmon for Pmon > 250 mm

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Crop Name: Broccoli Planting date: 01/02
Harvest: 21/04

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: ALEJO

General soil data:

Total available soil moisture (FC - WP) 100.0 mm/meter

Maximum rain infiltration rate	25	mm/day
Maximum rooting depth	120	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	100.0	mm/meter

CROP WATER REQUIREMENTS

ETo station: Penuelitas　　Crop: Broccoli
Rain station: Penuelitas　　Planting date: 01/02

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Feb	1	Deve	0.71	3.24	32.4	3.9	28.5
Feb	2	Deve	0.95	4.96	49.6	3.5	46.1
Feb	3	Mid	1.10	5.97	47.7	3.0	44.7
Mar	1	Mid	1.10	6.15	61.5	2.3	59.2
Mar	2	Mid	1.10	6.41	64.1	1.7	62.4
Mar	3	Late	1.09	6.66	73.2	2.5	70.7
Apr	1	Late	1.06	6.76	67.6	3.1	64.5
Apr	2	Late	1.02	6.85	68.5	3.6	65.0
Apr	3	Late	1.00	6.87	6.9	0.6	6.9
					471.5	24.2	447.9

CROP IRRIGATION SCHEDULE

ETo station: Penuelitas　　Crop: Broccoli　　Planting date: 01/02
Rain station: Penuelitas　　Soil: ALEJO　　Harvest date: 21/04

Yield red.: 15.6 %

Crop scheduling options
Timing: Irrigate at user defined intervals
Application: User defined application depths
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Feb	1	Init	0.0	1.00	100	6	21.0	0.0	17.8	30.0	3.47
7 Feb	7	Init	2.0	1.00	100	29	32.0	0.0	16.5	45.7	0.88
27 Feb	27	Mid	1.5	0.16	63	95	32.0	25.1	0.0	45.7	0.26
7 Mar	35	Mid	1.1	0.28	66	92	32.0	23.0	0.0	45.7	0.66
14 Mar	42	Mid	0.0	0.33	73	90	32.0	22.2	0.0	45.7	0.76
21 Mar	49	Mid	0.0	0.32	73	91	32.0	22.5	0.0	45.7	0.76
28 Mar	56	End	0.0	0.33	74	90	32.0	22.2	0.0	45.7	0.76
31 Mar	59	End	0.0	1.00	100	70	32.0	10.2	0.0	45.7	1.76
4 Apr	63	End	0.0	1.00	100	59	32.0	3.7	0.0	45.7	1.32
7 Apr	66	End	1.5	1.00	100	37	32.0	0.0	9.6	45.7	1.76
11 Apr	70	End	0.0	1.00	100	45	32.0	0.0	4.9	45.7	1.32
15 Apr	74	End	0.0	1.00	100	43	32.0	0.0	6.4	45.7	1.32
18 Apr	77	End	0.0	1.00	100	31	32.0	0.0	13.2	45.7	1.76
21 Apr	End	End	0.0	1.00	0	23					

Totals:

Total gross irrigation	578.6	mm	Total rainfall	23.7	mm
Total net irrigation	405.0	mm	Effective rainfall	23.7	mm
Total irrigation losses	68.4	mm	Total rain loss	0.0	mm
Actual water use by crop	374.1	mm	Moist deficit at harvest	13.7	mm
Potential water use by crop	464.6	mm	Actual irrigation requirement	440.9	mm
Efficiency irrigation schedule	83.1	%	Efficiency rain	100.0	%
Deficiency irrigation schedule	19.5	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	11.1	38.6	6.3	19.5	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	10.6	36.7	6.0	15.6	%
Cumulative yield reduction	0.0	10.6	43.4	46.7		%

Annex table 3: Second crop cycle Alejo

Alejandro: current Irrigation

Weather data:

Station: Penuelitas

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1

November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

Station: Penuelitas

Eff. rain method: USDA Soil Conservation Service formula:
Peff = Pmon * (125 - 0.2 * Pmon) / 125 for Pmon <= 250 mm
Peff = 125 + 0.1 * Pmon for Pmon > 250 mm

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Crop Name: Broccoli Planting date: 01/11
Harvest: 19/01

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: Alejandro

General soil data:

Total available soil moisture (FC - WP)	190.0	mm/meter
Maximum rain infiltration rate	30	mm/day
Maximum rooting depth	120	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	190.0	mm/meter

CROPPING PATTERN DATA

Cropping pattern name:

No. %	Crop file	Crop name	Planting date	Harvest date
1	BROCCOLI.CRO	Broccoli	01/11	19/01
2	BROCCOLI.CRO	Broccoli	22/02	12/05

CROP WATER REQUIREMENTS

ETo station: Penuelitas Crop: Broccoli
Rain station: Penuelitas Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Deve	0.71	2.63	26.3	4.7	21.6
Nov	2	Deve	0.95	3.34	33.4	1.7	31.6
Nov	3	Mid	1.10	3.76	37.6	1.9	35.7
Dec	1	Mid	1.10	3.65	36.5	2.1	34.3
Dec	2	Mid	1.10	3.53	35.3	1.8	33.5
Dec	3	Late	1.08	3.51	38.6	2.8	35.7
Jan	1	Late	1.05	3.29	32.9	4.3	28.6
Jan	2	Late	1.02	3.16	28.4	4.8	23.1
					268.9	24.2	244.1

CROP IRRIGATION SCHEDULE

ETo station: Penuelitas Crop: Broccoli
Planting date: 01/11
Rain station: Penuelitas Soil: Alejandro
Harvest date: 19/01

Yield red.: 0.0 %

Crop scheduling options

Timing: Irrigate at user defined intervals
Application: User defined application depths
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Nov	1	Init	0.0	1.00	100	3	11.0	0.0	8.4	15.7	1.82
4 Nov	4	Init	0.0	1.00	100	6	11.0	0.0	5.5	15.7	0.61
7 Nov	7	Init	2.4	1.00	100	5	11.0	0.0	5.5	15.7	0.61
10 Nov	10	Dev	0.0	1.00	100	8	11.0	0.0	3.1	15.7	0.61
13 Nov	13	Dev	0.8	1.00	100	9	11.0	0.0	1.8	15.7	0.61
16 Nov	16	Dev	0.0	1.00	100	9	11.0	0.0	1.0	15.7	0.61
19 Nov	19	Dev	0.0	1.00	100	9	11.0	0.0	1.0	15.7	0.61
21 Nov	21	Mid	0.0	1.00	100	6	11.0	0.0	3.9	15.7	0.91
24 Nov	24	Mid	0.0	1.00	100	9	11.0	0.0	0.7	15.7	0.61
27 Nov	27	Mid	0.9	1.00	100	9	11.0	0.0	0.7	15.7	0.61
30 Nov	30	Mid	0.0	1.00	100	10	11.0	0.3	0.0	15.7	0.61
3 Dec	33	Mid	1.1	1.00	100	9	11.0	0.0	0.9	15.7	0.61
6 Dec	36	Mid	0.0	1.00	100	10	11.0	0.0	0.1	15.7	0.61
9 Dec	39	Mid	0.0	1.00	100	10	11.0	0.0	0.1	15.7	0.61
12 Dec	42	Mid	0.0	1.00	100	9	11.0	0.0	0.3	15.7	0.61
15 Dec	45	Mid	0.0	1.00	100	9	22.0	0.0	11.4	31.4	1.21
18 Dec	48	Mid	0.0	1.00	100	8	22.0	0.0	12.3	31.4	1.21
21 Dec	51	End	0.0	1.00	100	9	22.0	0.0	11.4	31.4	1.21
24 Dec	54	End	0.0	1.00	100	8	22.0	0.0	12.9	31.4	1.21
27 Dec	57	End	1.4	1.00	100	8	22.0	0.0	12.9	31.4	1.21
30 Dec	60	End	0.0	1.00	100	9	22.0	0.0	11.5	31.4	1.21
2 Jan	63	End	0.0	1.00	100	9	22.0	0.0	11.9	31.4	1.21
5 Jan	66	End	0.0	1.00	100	9	22.0	0.0	12.1	31.4	1.21
8 Jan	69	End	0.0	1.00	100	7	22.0	0.0	14.3	31.4	1.21
11 Jan	72	End	0.0	1.00	100	9	22.0	0.0	12.3	31.4	1.21
14 Jan	75	End	0.0	1.00	100	6	22.0	0.0	15.3	31.4	1.21
17 Jan	78	End	2.7	1.00	100	6	22.0	0.0	15.3	31.4	1.21
19 Jan	End	End	0.0	1.00	0	3					

Totals:

Total gross irrigation 612.9 mm
Total rainfall 25.2 mm

Total net irrigation 429.0 mm

Effective rainfall 20.2 mm
Total irrigation losses 186.6 mm
Total rain loss 5.1 mm

Actual water use by crop 265.7 mm
Moist deficit at harvest 3.2 mm
Potential water use by crop 265.7 mm
Actual irrigation requirement 245.5 mm

Efficiency irrigation schedule 56.5 %
Efficiency rain 79.9 %
Deficiency irrigation schedule 0.0 %

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.0	0.0	0.0	0.0	%
Cumulative yield reduction	0.0	0.0	0.0	0.0		%

Second Crop Cycle February

Station: Penuelitas

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

Station: Penuelitas

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	**498.7**	**438.5**

DRY CROP DATA

Crop Name: Broccoli Planting date: 01/02 Harvest: 21/04

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: Alejandro

General soil data:

Total available soil moisture (FC - WP)	190.0	mm/meter
Maximum rain infiltration rate	30	mm/day
Maximum rooting depth	120	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	190.0	mm/meter

CROP WATER REQUIREMENTS

ETo station: Penuelitas Crop: Broccoli
Rain station: Penuelitas Planting date: 01/02

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Feb	1	Deve	0.71	3.24	32.4	3.9	28.5
Feb	2	Deve	0.95	4.96	49.6	3.5	46.1
Feb	3	Mid	1.10	5.97	47.7	3.0	44.7
Mar	1	Mid	1.10	6.15	61.5	2.3	59.2
Mar	2	Mid	1.10	6.41	64.1	1.7	62.4
Mar	3	Late	1.09	6.66	73.2	2.5	70.7
Apr	1	Late	1.06	6.76	67.6	3.1	64.5
Apr	2	Late	1.02	6.85	68.5	3.6	65.0
Apr	3	Late	1.00	6.87	6.9	0.6	6.9
					471.5	**24.2**	**447.9**

CROP IRRIGATION SCHEDULE

Planting date: 01/02
Soil: Alejandro Harvest date: 21/04

Yield red.: 0.0 %

Crop scheduling options
Timing: Irrigate at user defined intervals
Application: User defined application depths
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Feb	1	Init	0.0	1.00	100	3	11.0	0.0	7.8	15.7	1.82
4 Feb	4	Init	0.0	1.00	100	8	11.0	0.0	3.3	15.7	0.61
7 Feb	7	Init	2.0	1.00	100	8	11.0	0.0	3.3	15.7	0.61
10 Feb	10	Dev	0.0	1.00	100	9	11.0	0.0	1.3	15.7	0.61
13 Feb	13	Dev	1.8	1.00	100	12	11.0	2.1	0.0	15.7	0.61
16 Feb	16	Dev	0.0	1.00	100	15	11.0	6.0	0.0	15.7	0.61
19 Feb	19	Dev	0.0	1.00	100	17	11.0	8.1	0.0	15.7	0.61
21 Feb	21	Mid	0.0	1.00	100	17	11.0	8.0	0.0	15.7	0.91
24 Feb	24	Mid	0.0	1.00	100	21	11.0	13.3	0.0	15.7	0.61
27 Feb	27	Mid	1.5	1.00	100	26	11.0	18.7	0.0	15.7	0.61
2 Mar	30	Mid	0.0	1.00	100	32	11.0	26.0	0.0	15.7	0.61
5 Mar	33	Mid	0.0	1.00	100	38	11.0	32.3	0.0	15.7	0.61
8 Mar	36	Mid	0.0	1.00	100	44	11.0	38.6	0.0	15.7	0.61
11 Mar	39	Mid	0.0	1.00	100	50	11.0	46.3	0.0	15.7	0.61
14 Mar	42	Mid	0.0	1.00	100	57	11.0	53.7	0.0	15.7	0.61
17 Mar	45	Mid	0.8	1.00	100	63	22.0	50.1	0.0	31.4	1.21
20 Mar	48	Mid	0.0	1.00	100	61	22.0	47.3	0.0	31.4	1.21
23 Mar	51	End	1.3	1.00	100	58	22.0	44.0	0.0	31.4	1.21
26 Mar	54	End	0.0	1.00	100	56	22.0	42.0	0.0	31.4	1.21
29 Mar	57	End	0.0	1.00	100	53	22.0	38.7	0.0	31.4	1.21
1 Apr	60	End	0.0	1.00	100	52	22.0	36.8	0.0	31.4	1.21
4 Apr	63	End	0.0	1.00	100	49	22.0	33.5	0.0	31.4	1.21
7 Apr	66	End	1.5	1.00	100	46	22.0	30.2	0.0	31.4	1.21
10 Apr	69	End	0.0	1.00	100	44	22.0	28.5	0.0	31.4	1.21
13 Apr	72	End	1.8	1.00	100	41	22.0	25.3	0.0	31.4	1.21
16 Apr	75	End	0.0	1.00	100	40	22.0	23.8	0.0	31.4	1.21
19 Apr	78	End	0.0	1.00	100	37	22.0	20.6	0.0	31.4	1.21
21 Apr	End	End	0.0	1.00	0	24					

Totals:

Total gross irrigation	612.9	mm	Total rainfall	23.7	mm
Total net irrigation	429.0	mm	Effective rainfall	23.7	mm
Total irrigation losses	15.6	mm	Total rain loss	0.0	mm
Actual water use by crop	464.6	mm	Moist deficit at harvest	27.5	mm
Potential water use by crop	464.6	mm	Actual irrigation requirement	440.9	mm
Efficiency irrigation schedule	96.4	%	Efficiency rain	100.0	%
Deficiency irrigation schedule	0.0	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.0	0.0	0.0	0.0	%

Cumulative yield reduction	0.0	0.0	0.0	0.0	%

Annex table 4: Current irrigation Alejandro

Paco: Current Irrigation

Weather data:

Station: Penuelitas

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

Station: Penuelitas

Eff. rain method: USDA Soil Conservation Service formula:

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Crop Name: Broccoli Planting date: 01/11
Harvest: 19/01

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: PACO

General soil data:

Total available soil moisture (FC - WP)	190.0	mm/meter
Maximum rain infiltration rate	11	mm/day
Maximum rooting depth	120	centimetres
Initial soil moisture depletion (as % TA)	0	%
Initial available soil moisture	190.0	mm/meter

CROPPING PATTERN DATA
(File: untitled)

Cropping pattern name:

No.	Crop file	Crop name	Planting date	Harvest date	Area %
1	BROCCOLI.CRO	Broccoli	01/11	19/01	
2	BROCCOLI.CRO	Broccoli	22/02	12/05	

CROP WATER REQUIREMENTS

ETo station: Penuelitas　　　　Crop: Broccoli
Rain station: Penuelitas　　　　Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Deve	0.71	2.63	26.3	4.7	21.6
Nov	2	Deve	0.95	3.34	33.4	1.7	31.6
Nov	3	Mid	1.10	3.76	37.6	1.9	35.7
Dec	1	Mid	1.10	3.65	36.5	2.1	34.3
Dec	2	Mid	1.10	3.53	35.3	1.8	33.5
Dec	3	Late	1.08	3.51	38.6	2.8	35.7
Jan	1	Late	1.05	3.29	32.9	4.3	28.6
Jan	2	Late	1.02	3.16	28.4	4.8	23.1
					268.9	**24.2**	**244.1**

CROP IRRIGATION SCHEDULE

Planting date: 01/11
Rain station: Penuelitas　　　Soil: PACO
Harvest date: 19/01

Yield red.: 0.0 %

Crop scheduling options
　Timing: Irrigate at user defined intervals
　Application: User defined application depths
　Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Nov	1	Init	0.0	1.00	100	3	11.0	0.0	8.4	15.7	1.82
4 Nov	4	Init	0.0	1.00	100	6	11.0	0.0	5.5	15.7	0.61
7 Nov	7	Init	2.4	1.00	100	5	11.0	0.0	5.5	15.7	0.61
10 Nov	10	Dev	0.0	1.00	100	8	11.0	0.0	3.1	15.7	0.61
13 Nov	13	Dev	0.8	1.00	100	9	11.0	0.0	1.8	15.7	0.61
16 Nov	16	Dev	0.0	1.00	100	9	11.0	0.0	1.0	15.7	0.61
19 Nov	19	Dev	0.0	1.00	100	9	11.0	0.0	1.0	15.7	0.61
21 Nov	21	Mid	0.0	1.00	100	6	11.0	0.0	3.9	15.7	0.91
24 Nov	24	Mid	0.0	1.00	100	9	11.0	0.0	0.7	15.7	0.61
27 Nov	27	Mid	0.9	1.00	100	9	11.0	0.0	0.7	15.7	0.61
30 Nov	30	Mid	0.0	1.00	100	10	11.0	0.3	0.0	15.7	0.61
3 Dec	33	Mid	1.1	1.00	100	9	11.0	0.0	0.9	15.7	0.61
6 Dec	36	Mid	0.0	1.00	100	10	11.0	0.0	0.1	15.7	0.61
9 Dec	39	Mid	0.0	1.00	100	10	11.0	0.0	0.1	15.7	0.61
12 Dec	42	Mid	0.0	1.00	100	9	11.0	0.0	0.3	15.7	0.61
15 Dec	45	Mid	0.0	1.00	100	9	22.0	0.0	11.4	31.4	1.21
18 Dec	48	Mid	0.0	1.00	100	8	22.0	0.0	12.3	31.4	1.21
21 Dec	51	End	0.0	1.00	100	9	22.0	0.0	11.4	31.4	1.21
24 Dec	54	End	0.0	1.00	100	8	22.0	0.0	12.9	31.4	1.21
27 Dec	57	End	1.4	1.00	100	8	22.0	0.0	12.9	31.4	1.21

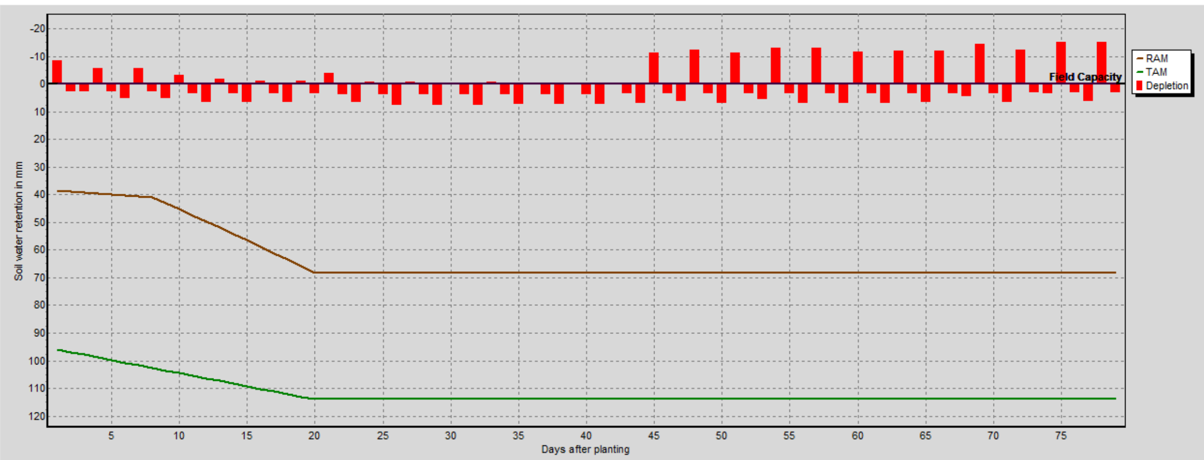
30 Dec	60	End	0.0	1.00	100	9	22.0	0.0	11.5	31.4	1.21
2 Jan	63	End	0.0	1.00	100	9	22.0	0.0	11.9	31.4	1.21
5 Jan	66	End	0.0	1.00	100	9	22.0	0.0	12.1	31.4	1.21
8 Jan	69	End	0.0	1.00	100	7	22.0	0.0	14.3	31.4	1.21
11 Jan	72	End	0.0	1.00	100	9	22.0	0.0	12.3	31.4	1.21
14 Jan	75	End	0.0	1.00	100	6	22.0	0.0	15.3	31.4	1.21
17 Jan	78	End	2.7	1.00	100	6	22.0	0.0	15.3	31.4	1.21
19 Jan	End	End	0.0	1.00	0	3					

Totals:

Total gross irrigation	612.9	mm
Total rainfall	25.2	mm
Total net irrigation	429.0	mm
Effective rainfall	20.2	mm
Total irrigation losses	186.6	mm
Total rain loss	5.1	mm
Actual water use by crop	265.7	mm
Moist deficit at harvest	3.2	mm
Potential water use by crop	265.7	mm
Actual irrigation requirement	245.5	mm
Efficiency irrigation schedule	56.5	%
Efficiency rain	79.9	%
Deficiency irrigation schedule	0.0	%

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.0	0.0	0.0	0.0	%
Cumulative yield reduction	0.0	0.0	0.0	0.0		%



Annex table 5: Current irrigation Paco

Second Crop Cycle February

Weather data:

Station: Penuelitas

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

Station: Penuelitas

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Crop Name: Broccoli Planting date: 01/02 Harvest: 21/04

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	

Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: PACO

General soil data:

Total available soil moisture (FC - WP)	190.0	mm/meter
Maximum rain infiltration rate	11	mm/day
Maximum rooting depth	120	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	190.0	mm/meter

CROP WATER REQUIREMENTS

ETo station: Penuelitas　　Crop: Broccoli
Rain station: Penuelitas　　Planting date: 01/02

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Feb	1	Deve	0.71	3.24	32.4	3.9	28.5
Feb	2	Deve	0.95	4.96	49.6	3.5	46.1
Feb	3	Mid	1.10	5.97	47.7	3.0	44.7
Mar	1	Mid	1.10	6.15	61.5	2.3	59.2
Mar	2	Mid	1.10	6.41	64.1	1.7	62.4
Mar	3	Late	1.09	6.66	73.2	2.5	70.7
Apr	1	Late	1.06	6.76	67.6	3.1	64.5
Apr	2	Late	1.02	6.85	68.5	3.6	65.0
Apr	3	Late	1.00	6.87	6.9	0.6	6.9
					471.5	24.2	447.9

CROP IRRIGATION SCHEDULE

ETo station: Penuelitas　　Crop: Broccoli　　Planting date: 01/02
Rain station: Penuelitas　　Soil: PACO　　Harvest date: 21/04

Yield red.: 0.0 %

Crop scheduling options
Timing: Irrigate at user defined intervals
Application: User defined application depths
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Feb	1	Init	0.0	1.00	100	3	11.0	0.0	7.8	15.7	1.82
4 Feb	4	Init	0.0	1.00	100	8	11.0	0.0	3.3	15.7	0.61
7 Feb	7	Init	2.0	1.00	100	8	11.0	0.0	3.3	15.7	0.61

10 Feb	10	Dev	0.0	1.00	100	9	11.0	0.0	1.3	15.7	0.61
13 Feb	13	Dev	1.8	1.00	100	12	11.0	2.1	0.0	15.7	0.61
16 Feb	16	Dev	0.0	1.00	100	15	11.0	6.0	0.0	15.7	0.61
19 Feb	19	Dev	0.0	1.00	100	17	11.0	8.1	0.0	15.7	0.61
21 Feb	21	Mid	0.0	1.00	100	17	11.0	8.0	0.0	15.7	0.91
24 Feb	24	Mid	0.0	1.00	100	21	11.0	13.3	0.0	15.7	0.61
27 Feb	27	Mid	1.5	1.00	100	26	11.0	18.7	0.0	15.7	0.61
2 Mar	30	Mid	0.0	1.00	100	32	11.0	26.0	0.0	15.7	0.61
5 Mar	33	Mid	0.0	1.00	100	38	11.0	32.3	0.0	15.7	0.61
8 Mar	36	Mid	0.0	1.00	100	44	11.0	38.6	0.0	15.7	0.61
11 Mar	39	Mid	0.0	1.00	100	50	11.0	46.3	0.0	15.7	0.61
14 Mar	42	Mid	0.0	1.00	100	57	11.0	53.7	0.0	15.7	0.61
17 Mar	45	Mid	0.8	1.00	100	63	22.0	50.1	0.0	31.4	1.21
20 Mar	48	Mid	0.0	1.00	100	61	22.0	47.3	0.0	31.4	1.21
23 Mar	51	End	1.3	1.00	100	58	22.0	44.0	0.0	31.4	1.21
26 Mar	54	End	0.0	1.00	100	56	22.0	42.0	0.0	31.4	1.21
29 Mar	57	End	0.0	1.00	100	53	22.0	38.7	0.0	31.4	1.21
1 Apr	60	End	0.0	1.00	100	52	22.0	36.8	0.0	31.4	1.21
4 Apr	63	End	0.0	1.00	100	49	22.0	33.5	0.0	31.4	1.21
7 Apr	66	End	1.5	1.00	100	46	22.0	30.2	0.0	31.4	1.21
10 Apr	69	End	0.0	1.00	100	44	22.0	28.5	0.0	31.4	1.21
13 Apr	72	End	1.8	1.00	100	41	22.0	25.3	0.0	31.4	1.21
16 Apr	75	End	0.0	1.00	100	40	22.0	23.8	0.0	31.4	1.21
19 Apr	78	End	0.0	1.00	100	37	22.0	20.6	0.0	31.4	1.21
21 Apr	End	End	0.0	1.00	0	24					

Totals:

Total gross irrigation	612.9	mm	Total rainfall	23.7	mm
Total net irrigation	429.0	mm	Effective rainfall	23.7	mm
Total irrigation losses	15.6	mm	Total rain loss	0.0	mm
Actual water use by crop	464.6	mm	Moist deficit at harvest	27.5	mm
Potential water use by crop	464.6	mm	Actual irrigation requirement	440.9	mm
Efficiency irrigation schedule	96.4	%	Efficiency rain	100.0	%
Deficiency irrigation schedule	0.0	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.0	0.0	0.0	0.0	%
Cumulative yield reduction	0.0	0.0	0.0	0.0		%

Iñaqui: Current Irrigation

Weather data:

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7

May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

Station: Penuelitas

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Crop Name: Broccoli Planting date: 01/11
Harvest: 19/01

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: Iñaqui

General soil data:

Total available soil moisture (FC - WP) 76.0 mm/meter

Maximum rain infiltration rate	8	mm/day
Maximum rooting depth	120	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	76.0	mm/meter

CROP WATER REQUIREMENTS

Planting date: 05/10

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Oct	1	Init	0.70	2.92	17.5	9.0	10.0
Oct	2	Deve	0.82	3.37	33.7	9.6	24.0
Oct	3	Mid	1.09	4.24	46.6	7.3	39.3
Nov	1	Mid	1.10	4.09	40.9	4.7	36.2
Nov	2	Mid	1.10	3.87	38.7	1.7	36.9
Nov	3	Late	1.10	3.72	37.2	1.9	35.3
Dec	1	Late	1.06	3.51	35.1	2.1	32.9
Dec	2	Late	1.03	3.29	32.9	1.8	31.1
Dec	3	Late	1.01	3.26	9.8	0.8	8.4
					292.4	39.0	254.2

CROP IRRIGATION SCHEDULE

Planting date: 01/11
Rain station: Penuelitas Soil: Iñaqui
Harvest date: 19/01

Yield red.: 0.0 %

Crop scheduling options
Timing: Irrigate at user defined intervals
Application: User defined application depths
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Nov	1	Init	0.0	1.00	100	7	7.0	0.0	4.4	10.0	1.16
3 Nov	3	Init	2.4	1.00	100	7	7.0	0.0	4.2	10.0	0.58
5 Nov	5	Init	0.0	1.00	100	13	7.0	0.0	1.7	10.0	0.58
7 Nov	7	Init	2.4	1.00	100	7	7.0	0.0	4.2	10.0	0.58
9 Nov	9	Dev	0.0	1.00	100	13	7.0	0.0	1.7	10.0	0.58
11 Nov	11	Dev	0.0	1.00	100	14	7.0	0.0	1.0	10.0	0.58
13 Nov	13	Dev	0.8	1.00	100	14	7.0	0.0	1.2	10.0	0.58
15 Nov	15	Dev	0.0	1.00	100	15	7.0	0.0	0.3	10.0	0.58
17 Nov	17	Dev	0.8	1.00	100	13	7.0	0.0	1.2	10.0	0.58
19 Nov	19	Dev	0.0	1.00	100	15	7.0	0.0	0.3	10.0	0.58
21 Nov	21	Mid	0.0	1.00	100	16	7.0	0.1	0.0	10.0	0.58
23 Nov	23	Mid	0.9	1.00	100	15	7.0	0.0	0.3	10.0	0.58
25 Nov	25	Mid	0.0	1.00	100	16	7.0	0.5	0.0	10.0	0.58
27 Nov	27	Mid	0.9	1.00	100	16	7.0	0.1	0.0	10.0	0.58
29 Nov	29	Mid	0.0	1.00	100	17	7.0	0.6	0.0	10.0	0.58
1 Dec	31	Mid	0.0	1.00	100	18	7.0	1.0	0.0	10.0	0.58
3 Dec	33	Mid	1.1	1.00	100	16	7.0	0.2	0.0	10.0	0.58
5 Dec	35	Mid	0.0	1.00	100	16	7.0	0.5	0.0	10.0	0.58

7 Dec	37	Mid	1.1	1.00	100	15	7.0	0.0	0.3	10.0	0.58
9 Dec	39	Mid	0.0	1.00	100	16	7.0	0.3	0.0	10.0	0.58
11 Dec	41	Mid	0.0	1.00	100	16	7.0	0.5	0.0	10.0	0.58
14 Dec	44	Mid	0.0	1.00	100	22	17.0	0.0	6.9	24.3	0.94
17 Dec	47	Mid	0.9	1.00	100	21	17.0	0.0	7.3	24.3	0.94
20 Dec	50	Mid	0.0	1.00	100	23	17.0	0.0	6.4	24.3	0.94
23 Dec	53	End	1.4	1.00	100	20	17.0	0.0	7.9	24.3	0.94
26 Dec	56	End	0.0	1.00	100	23	17.0	0.0	6.5	24.3	0.94
29 Dec	59	End	0.0	1.00	100	23	17.0	0.0	6.5	24.3	0.94
1 Jan	62	End	0.0	1.00	100	23	17.0	0.0	6.7	24.3	0.94
4 Jan	65	End	0.0	1.00	100	17	17.0	0.0	9.3	24.3	0.94
7 Jan	68	End	2.2	1.00	100	17	17.0	0.0	9.3	24.3	0.94
10 Jan	71	End	0.0	1.00	100	22	17.0	0.0	7.1	24.3	0.94
13 Jan	74	End	2.7	1.00	100	15	17.0	0.0	10.3	24.3	0.94
16 Jan	77	End	0.0	1.00	100	21	17.0	0.0	7.5	24.3	0.94
19 Jan	End	End	0.0	1.00	0	14					

Totals:

Total gross irrigation	501.4	mm	Total rainfall	25.2	mm
Total net irrigation	351.0	mm	Effective rainfall	21.0	mm
Total irrigation losses	112.6	mm	Total rain loss	4.2	mm
Actual water use by crop	265.7	mm	Moist deficit at harvest	6.3	mm
Potential water use by crop	265.7	mm	Actual irrigation requirement	244.7	mm
Efficiency irrigation schedule	67.9	%	Efficiency rain	83.4	%
Deficiency irrigation schedule	0.0	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.0	0.0	0.0	0.0	%
Cumulative yield reduction	0.0	0.0	0.0	0.0		%

Second Crop Cycle February

Weather data:

Station: Penuelitas

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2

Average 5.0

MONTHLY RAIN DATA

Station: Penuelitas

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Crop Name: Broccoli Planting date: 01/02 Harvest: 21/04

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: Iñaqui

General soil data:

Total available soil moisture (FC - WP)	76.0	mm/meter
Maximum rain infiltration rate	8	mm/day
Maximum rooting depth	120	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	76.0	mm/meter

CROP WATER REQUIREMENTS

Planting date: 01/02

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Feb	1	Deve	0.71	3.24	32.4	3.9	28.5
Feb	2	Deve	0.95	4.96	49.6	3.5	46.1
Feb	3	Mid	1.10	5.97	47.7	3.0	44.7
Mar	1	Mid	1.10	6.15	61.5	2.3	59.2
Mar	2	Mid	1.10	6.41	64.1	1.7	62.4
Mar	3	Late	1.09	6.66	73.2	2.5	70.7
Apr	1	Late	1.06	6.76	67.6	3.1	64.5
Apr	2	Late	1.02	6.85	68.5	3.6	65.0
Apr	3	Late	1.00	6.87	6.9	0.6	6.9
					471.5	24.2	447.9

CROP IRRIGATION SCHEDULE

date: 01/02
Rain station: Penuelitas Soil: Iñaqui
Harvest date: 21/04

Yield red.: 6.1 %

Crop scheduling options
Timing: Irrigate at user defined intervals
Application: User defined application depths
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Feb	1	Init	0.0	1.00	100	8	7.0	0.0	3.8	10.0	1.16
3 Feb	3	Init	2.0	1.00	100	11	7.0	0.0	2.5	10.0	0.58
5 Feb	5	Init	0.0	1.00	100	16	7.0	0.0	0.5	10.0	0.58
7 Feb	7	Init	2.0	1.00	100	11	7.0	0.0	2.5	10.0	0.58
9 Feb	9	Dev	0.0	1.00	100	16	7.0	0.0	0.5	10.0	0.58
11 Feb	11	Dev	0.0	1.00	100	19	7.0	1.2	0.0	10.0	0.58
13 Feb	13	Dev	1.8	1.00	100	22	7.0	2.3	0.0	10.0	0.58
15 Feb	15	Dev	0.0	1.00	100	28	7.0	5.3	0.0	10.0	0.58
17 Feb	17	Dev	1.8	1.00	100	30	7.0	6.4	0.0	10.0	0.58
19 Feb	19	Dev	0.0	1.00	100	36	7.0	9.3	0.0	10.0	0.58
21 Feb	21	Mid	0.0	1.00	100	44	7.0	13.2	0.0	10.0	0.58
23 Feb	23	Mid	1.5	1.00	100	52	10.0	13.6	0.0	14.3	0.83
25 Feb	25	Mid	0.0	1.00	100	56	10.0	15.6	0.0	14.3	0.83
27 Feb	27	Mid	1.5	1.00	100	57	10.0	15.9	0.0	14.3	0.83
1 Mar	29	Mid	0.0	1.00	100	62	10.0	18.1	0.0	14.3	0.83
3 Mar	31	Mid	1.1	1.00	100	64	10.0	19.2	0.0	14.3	0.83
5 Mar	33	Mid	0.0	1.00	100	69	10.0	21.5	0.0	14.3	0.83
7 Mar	35	Mid	1.1	1.00	100	72	10.0	22.7	0.0	14.3	0.83
9 Mar	37	Mid	0.0	0.92	96	76	10.0	24.5	0.0	14.3	0.83
11 Mar	39	Mid	0.0	0.82	91	79	10.0	25.9	0.0	14.3	0.83
13 Mar	41	Mid	0.8	0.77	89	80	10.0	26.4	0.0	14.3	0.83
16 Mar	44	Mid	0.0	0.45	72	88	17.0	23.2	0.0	24.3	0.94
19 Mar	47	Mid	0.0	0.60	84	85	17.0	21.5	0.0	24.3	0.94
22 Mar	50	Mid	0.0	0.61	86	84	17.0	21.5	0.0	24.3	0.94
25 Mar	53	End	0.0	0.66	89	83	17.0	20.9	0.0	24.3	0.94
28 Mar	56	End	0.0	0.69	90	82	17.0	20.6	0.0	24.3	0.94
31 Mar	59	End	0.0	0.64	88	84	17.0	21.2	0.0	24.3	0.94
3 Apr	62	End	1.5	0.69	89	83	17.0	20.6	0.0	24.3	0.94

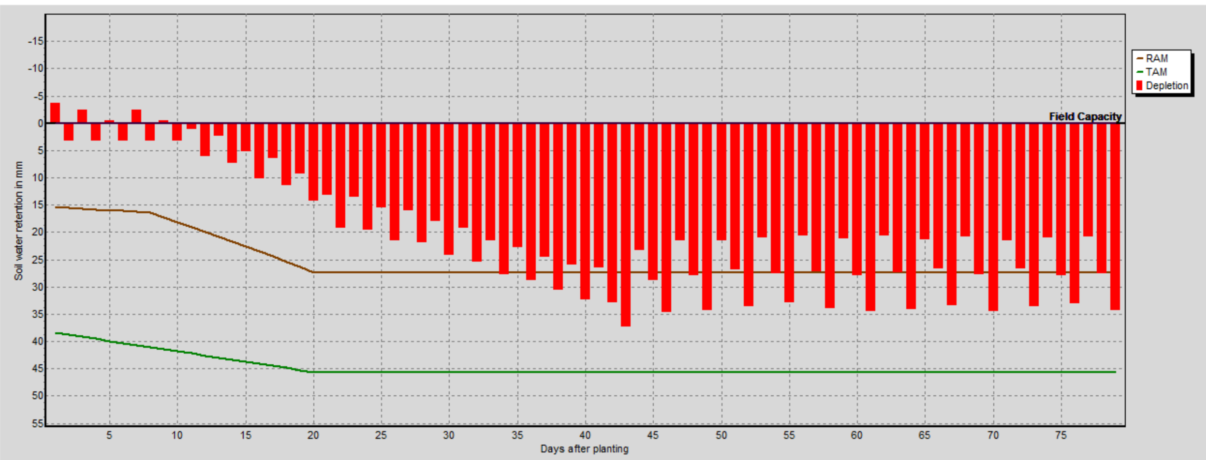
6 Apr	65	End	0.0	0.63	88	84	17.0	21.4	0.0	24.3	0.94
9 Apr	68	End	0.0	0.67	89	83	17.0	20.9	0.0	24.3	0.94
12 Apr	71	End	0.0	0.61	87	85	17.0	21.6	0.0	24.3	0.94
15 Apr	74	End	0.0	0.66	89	83	17.0	21.1	0.0	24.3	0.94
18 Apr	77	End	0.0	0.69	90	83	17.0	20.7	0.0	24.3	0.94
21 Apr	End	End	0.0	0.99	0	75					

Totals:

Total gross irrigation	544.3	mm	Total rainfall	23.7	mm
Total net irrigation	381.0	mm	Effective rainfall	23.7	mm
Total irrigation losses	9.8	mm	Total rain loss	0.0	mm
Actual water use by crop	429.2	mm	Moist deficit at harvest	34.4	mm
Potential water use by crop	464.6	mm	Actual irrigation requirement	440.9	mm
Efficiency irrigation schedule	97.4	%	Efficiency rain	100.0	%
Deficiency irrigation schedule	7.6	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	7.7	10.7	7.6	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.0	7.3	10.2	6.1	%
Cumulative yield reduction	0.0	0.0	7.3	16.7		%



Annex table 6: Current irrigation Inaqui

Edgar: Current Irrigation

Weather data:

Station: Penuelitas

	ETo mm/day
January	3.3

February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

Station: Penuelitas

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Planting date: 01/11   Harvest: 19/01

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: EDGAR

General soil data:

Total available soil moisture (FC - WP)	100.0	mm/meter
Maximum rain infiltration rate	25	mm/day
Maximum rooting depth	120	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	100.0	mm/meter

CROP WATER REQUIREMENTS

ETo station: Penuelitas   Crop: Broccoli
Rain station: Penuelitas   Planting date: 01/11

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Nov	1	Deve	0.71	2.63	26.3	4.7	21.6
Nov	2	Deve	0.95	3.34	33.4	1.7	31.6
Nov	3	Mid	1.10	3.76	37.6	1.9	35.7
Dec	1	Mid	1.10	3.65	36.5	2.1	34.3
Dec	2	Mid	1.10	3.53	35.3	1.8	33.5
Dec	3	Late	1.08	3.51	38.6	2.8	35.7
Jan	1	Late	1.05	3.29	32.9	4.3	28.6
Jan	2	Late	1.02	3.16	28.4	4.8	23.1
					268.9	24.2	244.1

CROP IRRIGATION SCHEDULE

ETo station: Penuelitas   Crop: Broccoli   Planting date: 01/11
Rain station: Penuelitas   Soil: EDGAR
Harvest date: 19/01

Yield red.: 8.6 %

Crop scheduling options
Timing: Irrigate at user defined intervals
Application: User defined application depths
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
6 Nov	6	Init	0.0	1.00	100	25	8.0	5.3	0.0	11.4	0.22
15 Nov	15	Dev	0.0	1.00	100	51	10.0	19.3	0.0	14.3	0.18
22 Nov	22	Mid	0.0	0.88	98	70	10.0	32.2	0.0	14.3	0.24
29 Nov	29	Mid	0.0	0.48	76	84	14.0	36.4	0.0	20.0	0.33
5 Dec	35	Mid	0.0	0.46	70	84	15.0	35.6	0.0	21.4	0.41
12 Dec	42	Mid	0.0	0.40	68	86	15.0	36.8	0.0	21.4	0.35
17 Dec	47	Mid	0.9	0.57	76	81	19.0	29.3	0.0	27.1	0.63
23 Dec	53	End	1.4	0.67	87	77	19.0	27.2	0.0	27.1	0.52
26 Dec	56	End	0.0	1.00	100	63	19.0	18.7	0.0	27.1	1.05
31 Dec	61	End	0.0	1.00	100	58	19.0	15.8	0.0	27.1	0.63
4 Jan	65	End	0.0	1.00	100	45	22.0	4.8	0.0	31.4	0.91
8 Jan	69	End	0.0	1.00	100	26	22.0	0.0	6.3	31.4	0.91
12 Jan	73	End	0.0	1.00	100	21	24.0	0.0	11.1	34.3	0.99
16 Jan	77	End	0.0	1.00	100	21	25.0	0.0	12.4	35.7	1.03
19 Jan	End	End	0.0	1.00	0	11					

Totals:

Total gross irrigation	344.3	mm	Total rainfall	25.2	mm
Total net irrigation	241.0	mm	Effective rainfall	19.7	mm
Total irrigation losses	29.8	mm	Total rain loss	5.5	mm
Actual water use by crop	237.3	mm	Moist deficit at harvest	6.3	mm
Potential water use by crop	265.7	mm	Actual irrigation requirement	246.0	mm
Efficiency irrigation schedule	87.7	%	Efficiency rain	78.2	%

Deficiency irrigation schedule 10.7 %

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	23.5	2.8	10.7	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.0	22.3	2.7	8.6	%
Cumulative yield reduction	0.0	0.0	22.3	24.4		%

Second Crop Cycle February

Weather data:

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Planting date: 01/02   Harvest: 21/04

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: EDGAR

General soil data:

Total available soil moisture (FC - WP)	100.0	mm/meter
Maximum rain infiltration rate	25	mm/day
Maximum rooting depth	120	centimeters
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	100.0	mm/meter

CROP WATER REQUIREMENTS

Planting date: 01/02

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Feb	1	Deve	0.71	3.24	32.4	3.9	28.5
Feb	2	Deve	0.95	4.96	49.6	3.5	46.1
Feb	3	Mid	1.10	5.97	47.7	3.0	44.7
Mar	1	Mid	1.10	6.15	61.5	2.3	59.2
Mar	2	Mid	1.10	6.41	64.1	1.7	62.4
Mar	3	Late	1.09	6.66	73.2	2.5	70.7
Apr	1	Late	1.06	6.76	67.6	3.1	64.5
Apr	2	Late	1.02	6.85	68.5	3.6	65.0
Apr	3	Late	1.00	6.87	6.9	0.6	6.9
					471.5	24.2	447.9

CROP IRRIGATION SCHEDULE

ETo station: Penuelitas Crop: Broccoli
Planting date: 01/02
Rain station: Penuelitas Soil: EDGAR
Harvest date: 21/04

Yield red.: 27.4 %

Crop scheduling options
- Timing: Irrigate at user defined intervals
- Application: User defined application depths
- Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
1 Feb	1	Init	0.0	1.00	100	6	1.0	2.2	0.0	1.4	0.17
6 Feb	6	Init	0.0	1.00	100	31	8.0	8.5	0.0	11.4	0.26
15 Feb	15	Dev	0.0	0.75	95	70	11.0	29.4	0.0	15.7	0.20
22 Feb	22	Mid	0.0	0.37	70	89	11.0	42.4	0.0	15.7	0.26
1 Mar	29	Mid	0.0	0.18	42	95	14.0	42.8	0.0	20.0	0.33
7 Mar	35	Mid	1.1	0.22	42	93	15.0	41.0	0.0	21.4	0.41
14 Mar	42	Mid	0.0	0.15	39	96	15.0	42.3	0.0	21.4	0.35
19 Mar	47	Mid	0.0	0.23	45	93	19.0	36.9	0.0	27.1	0.63
25 Mar	53	End	0.0	0.22	52	94	19.0	37.2	0.0	27.1	0.52
28 Mar	56	End	0.0	0.53	74	85	19.0	31.7	0.0	27.1	1.05
2 Apr	61	End	0.0	0.34	67	90	19.0	35.2	0.0	27.1	0.63
6 Apr	65	End	0.0	0.42	71	88	22.0	30.7	0.0	31.4	0.91
10 Apr	69	End	0.0	0.52	81	85	22.0	29.1	0.0	31.4	0.91
14 Apr	73	End	0.0	0.57	84	84	24.0	26.3	0.0	34.3	0.99
18 Apr	77	End	0.0	0.65	89	81	24.0	24.9	0.0	34.3	0.99
21 Apr	End	End	0.0	1.00	0	64					

Totals:

Total gross irrigation	347.1	mm	Total rainfall	23.7	mm
Total net irrigation	243.0	mm	Effective rainfall	23.7	mm
Total irrigation losses	0.0	mm	Total rain loss	0.0	mm
Actual water use by crop	305.3	mm	Moist deficit at harvest	38.6	mm
Potential water use by crop	464.6	mm	Actual irrigation requirement	440.9	mm
Efficiency irrigation schedule	100.0	%	Efficiency rain	100.0	%
Deficiency irrigation schedule	34.3	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	11.0	55.1	25.7	34.3	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	10.5	52.3	24.4	27.4	%
Cumulative yield reduction	0.0	10.5	57.3	67.7		%

Annex table 7: Current irrigation Edgar

CROPWAT calculated Irrigation

Bi-Daily Irrigation- fill up to field capacity

Weather data

Station: Penuelitas

	ETo mm/day
January	3.3
February	5.1
March	5.8
April	6.7
May	7.1
June	6.6
July	5.3
August	5.4
September	4.3
October	4.1
November	3.5
December	3.2
Average	5.0

MONTHLY RAIN DATA

	Rain mm	Eff rain mm
January	14.8	14.4
February	10.6	10.4
March	6.4	6.3
April	13.1	12.8
May	37.1	34.9
June	80.9	70.4
July	112.2	92.1
August	84.6	73.1
September	90.2	77.2
October	33.7	31.9
November	8.3	8.2
December	6.8	6.7
Total	498.7	438.5

DRY CROP DATA

Planting date: 20/09 Harvest: 08/12

Stage	initial	develop	mid	late	total
Length (days)	8	12	30	30	80
Kc Values	0.70	-->	1.05	0.95	
Rooting depth (m)	0.50	-->	0.60	0.60	
Critical depletion	0.40	-->	0.60	0.60	
Yield response f.	0.80	0.95	0.95	0.95	0.80
Cropheight (m)			0.40		

SOIL DATA

Soil name: ALEJO

General soil data:

Total available soil moisture (FC - WP)	100.0	mm/meter
Maximum rain infiltration rate	25	mm/day
Maximum rooting depth	120	centimetres
Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	100.0	mm/meter

CROP WATER REQUIREMENTS

Planting date: 20/09

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Sep	2	Init	0.70	3.01	3.0	2.8	3.0
Sep	3	Deve	0.72	3.05	30.5	22.2	8.3
Oct	1	Mid	0.98	4.10	41.0	15.0	26.0
Oct	2	Mid	1.10	4.53	45.3	9.6	35.7
Oct	3	Mid	1.10	4.31	47.4	7.3	40.1
Nov	1	Late	1.10	4.08	40.8	4.7	36.1
Nov	2	Late	1.08	3.78	37.8	1.7	36.1
Nov	3	Late	1.05	3.56	35.6	1.9	33.7
Dec	1	Late	1.02	3.35	26.8	1.7	24.7
Total:					308.2	67.0	243.5

CROP IRRIGATION SCHEDULE

Planting date: 20/09
Rain station: Penuelitas
Soil: ALEJO
Harvest date: 08/12

Yield red.: 0.0 %

Crop scheduling options
Timing: Irrigate at user defined intervals
Application: Refill to 100 % of field capacity
Field eff. 70 %

Table format: Irrigation schedule

Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
21 Sep	2	Init	0.0	1.00	100	12	6.1	0.0	0.0	8.7	0.50
23 Sep	4	Init	12.9	1.00	100	6	3.0	0.0	0.0	4.4	0.25
25 Sep	6	Init	0.0	1.00	100	12	6.1	0.0	0.0	8.7	0.50
27 Sep	8	Init	12.9	1.00	100	6	3.0	0.0	0.0	4.4	0.25
29 Sep	10	Dev	0.0	1.00	100	11	6.1	0.0	0.0	8.7	0.50
1 Oct	12	Dev	0.0	1.00	100	13	7.1	0.0	0.0	10.2	0.59
3 Oct	14	Dev	8.3	1.00	100	7	4.1	0.0	0.0	5.9	0.34
5 Oct	16	Dev	0.0	1.00	100	14	8.2	0.0	0.0	11.7	0.68
7 Oct	18	Dev	8.3	1.00	100	7	4.1	0.0	0.0	5.9	0.34
9 Oct	20	Dev	0.0	1.00	100	14	8.2	0.0	0.0	11.7	0.68
11 Oct	22	Mid	0.0	1.00	100	14	8.6	0.0	0.0	12.3	0.71

13 Oct	24	Mid	4.9	1.00	100	8	4.5	0.0	0.0	6.5	0.37
15 Oct	26	Mid	0.0	1.00	100	15	9.1	0.0	0.0	12.9	0.75
17 Oct	28	Mid	4.9	1.00	100	8	4.5	0.0	0.0	6.5	0.37
19 Oct	30	Mid	0.0	1.00	100	15	9.1	0.0	0.0	12.9	0.75
21 Oct	32	Mid	0.0	1.00	100	15	8.8	0.0	0.0	12.6	0.73
23 Oct	34	Mid	3.7	1.00	100	8	4.9	0.0	0.0	7.0	0.40
25 Oct	36	Mid	0.0	1.00	100	14	8.6	0.0	0.0	12.3	0.71
27 Oct	38	Mid	3.7	1.00	100	8	4.9	0.0	0.0	7.0	0.40
29 Oct	40	Mid	0.0	1.00	100	14	8.6	0.0	0.0	12.3	0.71
31 Oct	42	Mid	0.0	1.00	100	14	8.6	0.0	0.0	12.3	0.71
2 Nov	44	Mid	0.0	1.00	100	14	8.2	0.0	0.0	11.7	0.68
4 Nov	46	Mid	0.0	1.00	100	14	8.2	0.0	0.0	11.7	0.68
6 Nov	48	Mid	0.0	1.00	100	14	8.2	0.0	0.0	11.7	0.68
8 Nov	50	Mid	0.0	1.00	100	14	8.2	0.0	0.0	11.7	0.68
10 Nov	52	End	0.0	1.00	100	14	8.2	0.0	0.0	11.7	0.68
12 Nov	54	End	0.0	1.00	100	13	7.6	0.0	0.0	10.8	0.62
14 Nov	56	End	0.0	1.00	100	13	7.6	0.0	0.0	10.8	0.62
16 Nov	58	End	0.0	1.00	100	13	7.6	0.0	0.0	10.8	0.62
18 Nov	60	End	0.0	1.00	100	13	7.6	0.0	0.0	10.8	0.62
20 Nov	62	End	0.0	1.00	100	13	7.6	0.0	0.0	10.8	0.62
22 Nov	64	End	0.0	1.00	100	12	7.1	0.0	0.0	10.2	0.59
24 Nov	66	End	0.0	1.00	100	12	7.1	0.0	0.0	10.2	0.59
26 Nov	68	End	0.0	1.00	100	12	7.1	0.0	0.0	10.2	0.59
28 Nov	70	End	0.0	1.00	100	12	7.1	0.0	0.0	10.2	0.59
30 Nov	72	End	0.0	1.00	100	12	7.1	0.0	0.0	10.2	0.59
2 Dec	74	End	0.0	1.00	100	11	6.7	0.0	0.0	9.6	0.55
4 Dec	76	End	0.0	1.00	100	11	6.7	0.0	0.0	9.6	0.55
6 Dec	78	End	0.0	1.00	100	11	6.7	0.0	0.0	9.6	0.55
8 Dec	End	End	0.0	1.00	0	6					

Totals:

Total gross irrigation 386.7mm
Total rainfall 70.0mm
Total net irrigation 270.7mm
Effective rainfall 30.8mm
Total irrigation losses 0.0mm
Total rain loss 39.3mm

Actual water use by crop 304.8mm
Moist deficit at harvest 3.4mm
Potential water use by crop 304.8mm
Actual irrigation requirement 274.0mm
Efficiency irrigation schedule 100.0%
Efficiency rain 44.0%
Deficiency irrigation schedule 0.0%

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0.0	0.0	0.0	0.0	0.0	%
Yield response factor	0.80	0.95	0.95	0.95	0.80	
Yield reduction	0.0	0.0	0.0	0.0	0.0	%
Cumulative yield reduction	0.0	0.0	0.0	0.0		%

Irrigation based on depletion

Weather data:

	ETo mm/day
January	3,3
February	5,1
March	5,8
April	6,7
May	7,1
June	6,6
July	5,3
August	5,4
September	4,3
October	4,1
November	3,5
December	3,2
Average	5,0

MONTHLY RAIN DATA

	Rain mm	Eff rain mm
January	14,8	14,4
February	10,6	10,4
March	6,4	6,3
April	13,1	12,8
May	37,1	34,9
June	80,9	70,4
July	112,2	92,1
August	84,6	73,1
September	90,2	77,2
October	33,7	31,9
November	8,3	8,2
December	6,8	6,7
Total	498,7	438,5

SOIL DATA

Soil name: PACO

General soil data:

Total available soil moisture (FC - WP)	190,0	mm/meter
Maximum rain infiltration rate	11	mm/day
Maximum rooting depth	120	centimeters

Initial soil moisture depletion (as % TA	0	%
Initial available soil moisture	190,0	mm/meter

CROP IRRIGATION SCHEDULE

Planting date: 20.09.2016
Rain station: Penuelitas Soil: PACO
Harvest date: 08.12.2016

Yield red.: 0,0 %

Crop scheduling options
- Timing: Irrigate at 100 % depletion
- Application: Fixed application depth of 40 mm
- Field eff. 70 %

Table format: Irrigation schedule

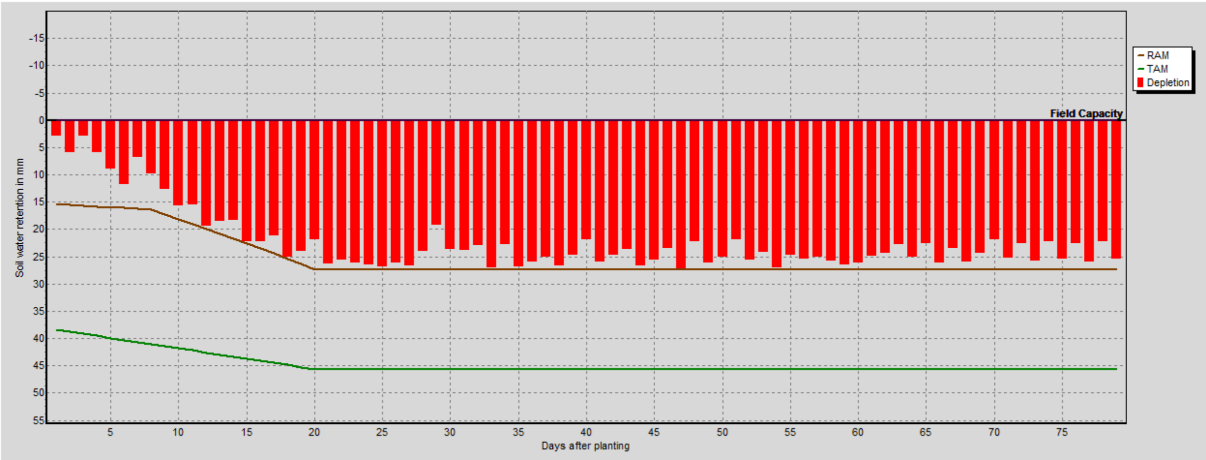
Date	Day	Stage	Rain mm	Ks fract.	Eta %	Depl %	Net Irr mm	Deficit mm	Loss mm	Gr. Irr mm	Flow l/s/ha
19 Oct	30	Mid	0,0	1,00	100	60	40,0	28,8	0,0	57,1	0,22
30 Oct	41	Mid	0,0	1,00	100	60	40,0	29,0	0,0	57,1	0,60
10 Nov	52	End	0,0	1,00	100	61	40,0	29,2	0,0	57,1	0,60
21 Nov	63	End	0,0	1,00	100	60	40,0	28,9	0,0	57,1	0,60
4 Dec	76	End	0,0	1,00	100	63	40,0	31,4	0,0	57,1	0,51
8 Dec	End	End	0,0	1,00	0	35					

Totals:

Total gross irrigation	285,7	mm	Total rainfall	70,0	mm
Total net irrigation	200,0	mm	Effective rainfall	66,3	mm
Total irrigation losses	0,0	mm	Total rain loss	3,8	mm
Actual water use by crop	304,8	mm	Moist deficit at harvest	40,4	mm
Potential water use by crop	304,8	mm	Actual irrigation requirement	238,5	mm
Efficiency irrigation schedule	100,0	%	Efficiency rain	94,6	%
Deficiency irrigation schedule	0,0	%			

Yield reductions:

Stagelabel	A	B	C	D	Season	
Reductions in ETc	0,0	0,0	0,0	0,0	0,0	%
Yield response factor	0,80	0,95	0,95	0,95	0,80	
Yield reduction	0,0	0,0	0,0	0,0	0,0	%
Cumulative yield reduction	0,0	0,0	0,0	0,0		%



Annex table 8: Irrigation based on depletion