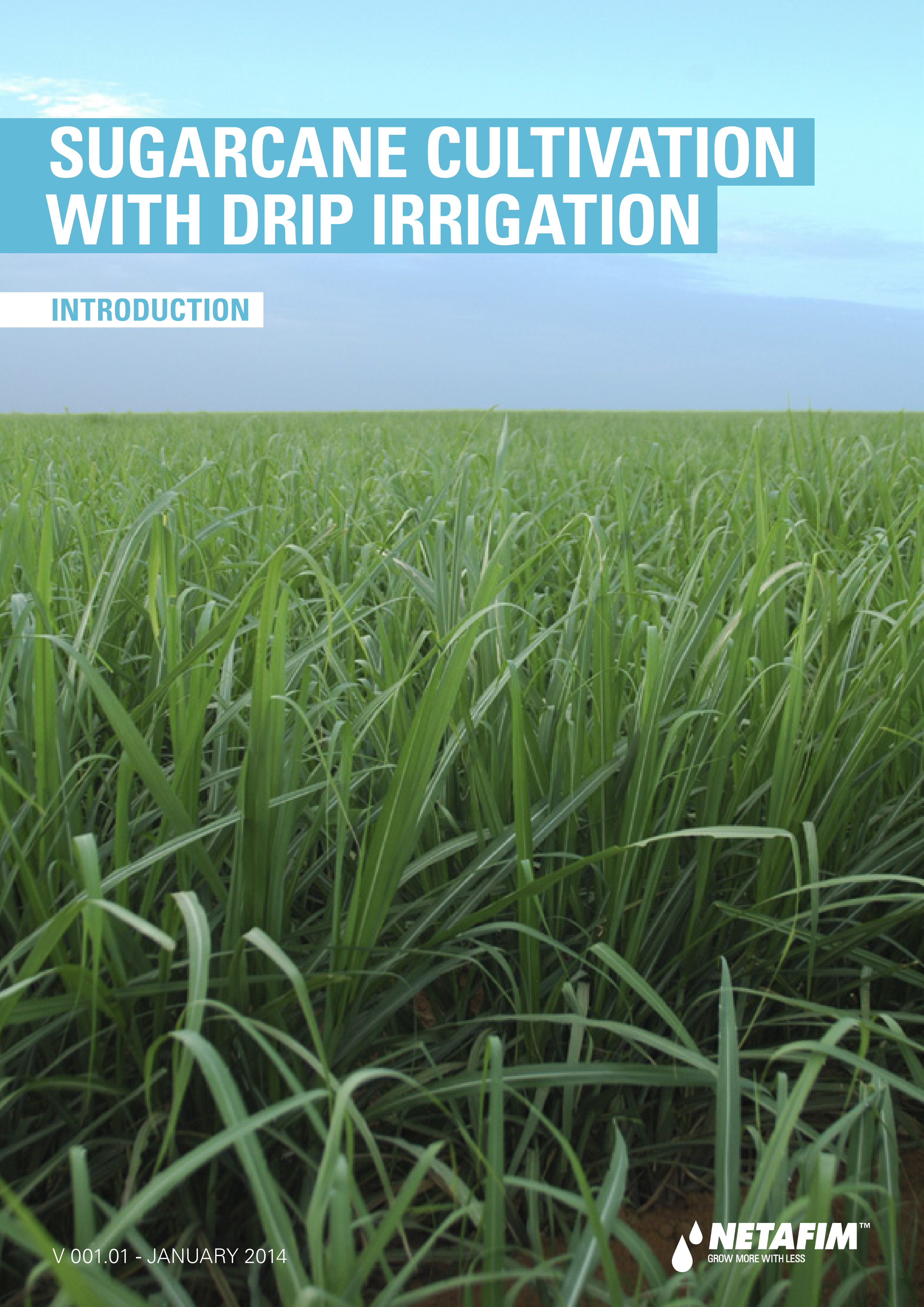
SUGARCANE CULTIVATION WITH DRIP IRRIGATION

INTRODUCTION



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In the event that you are reading this manual in a language other than the English language, you acknowledge and agree that the English language version shall prevail in case of inconsistency or contradiction in interpretation or translation.

Paragraphs in the introduction chapter, page 6, and The influence of soil pH on nutrient availability diagram, page 45, courtesy of Yara's Sugarcane Plantmaster™.

CONTENTS

ABOUT THIS DOCUMENT

Aim of this document

This document provides introductory information related to the implementation of drip irrigation for sugarcane growing.

The information in this document will help the client investing in an irrigation system for sugarcane cultivation understand the basic considerations involved in the choice of irrigation method.

Each chapter in this document covers a specific aspect of sugarcane growing:
financial and commercial considerations, site selection issues, engineering properties, operational procedures, agronomical concerns, maintenance requirements, etc.

Thorough reading of this document will provide the sugarcane grower with essential information that will help him/her take full advantage of the precision, efficiency, and practical benefits of sugarcane growing with a drip irrigation system, so that it delivers the most value.

Safety instructions

All local safety regulations must be applied when installing, operating, maintaining and troubleshooting the Netafim™ drip irrigation system and its components.

WARNING
In an agricultural environment - always wear protective footwear.

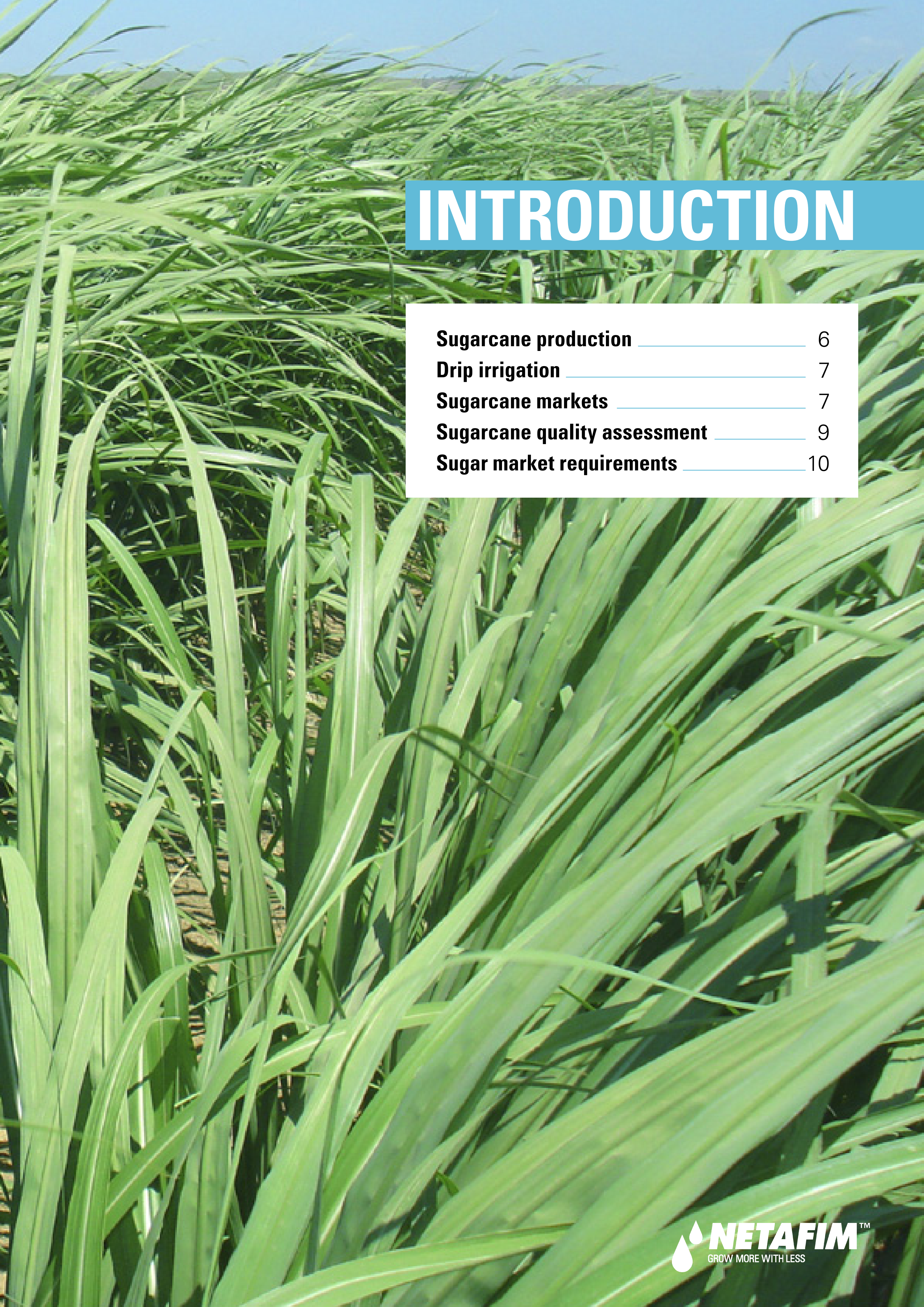
WARNING
Only authorized electricians are permitted to perform electrical installations!
Electrical installations must comply with the local safety standards and regulations.

WARNING
Measures must be taken to prevent infiltration of fertilizers, acids and chemicals into the water source.

ACID HAZARD
When not handled properly, fertilizers and acids used for Nutrigation™ may cause serious injury or even death. They may also damage the crop, the soil, the environment and the irrigation system.
Proper handling of fertilizers and chemicals is the responsibility of the grower.
Always observe the fertilizer/acid manufacturer's instructions and the regulations issued by the relevant local authority.

WARNING
When handling fertilizers, acid or other chemicals, always use protective equipment, gloves and goggles.

CAUTION
When opening or closing any manual valve, always do so gradually, to prevent damage to the system by water hammer.



INTRODUCTION

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Sugarcane production

Sugarcane (Saccarum officinarum) is a perennial grass that originated in Asia, probably in New Guinea.

Nearly 1,800 million tons of sugarcane are produced annually across almost 26 million hectares worldwide.

Most of the rain- fed and irrigated commercial sugarcane is grown between 35°N and 35°S of the equator.

Sugarcane is globally the main source of commercial sugar, accounting for nearly 70% of the world sugar production.

In the last decade global sugar consumption has been increasing at a steady rate of 2% per year.

In view of the diminishing petroleum reserves and the global need for environment-friendly fuel, many countries are seeking alternative renewable fuel resources. Bio-fuel production has tripled over the last decade.

In the 21st century, sugarcane has emerged as the most efficient source of ethanol.
Per-unit-area yields of ethanol from sugarcane are at least double that produced from wheat or maize.

Sugarcane is a multipurpose crop that also provides a series of added-value products such as animal feed, antibiotics, particle board, biofertilizer and raw material for generating electricity.

Global sugarcane production (2012)

Country (area)	Production (ton)	Area harvested (ha)	Yield (ton/ha)
Brazil	670,757,958	9,407,078	71.3
India	347,870,000	5,090,000	68.3
China, mainland	123,460,500	1,794,520	68.8
Thailand	96,500,000	1,300,000	74.2
Pakistan	58,038,000	1,046,000	55.5
Mexico	50,946,483	735,126	69.3
Cuba	16,200,000	510,000	31.8
Indonesia	26,341,600	456,700	57.7
Philippines	30,000,000	433,301	69.2
USA	27,900,000	370,000	75.4
Others	325,799,995	4,619,431	58.8
World total	**1,773,814,536**	**25,762,156**	**59.4**

(Source: FAO statistics - 2012)

Climatic factors, most notably water supply, are predominant factors affecting production.

The limited cultivable area available for expansion and the continuing conversion of agricultural land for industrial and construction purposes necessitate increased yield per cultivated hectare in order to increase overall production.

Quality planting material, improved agronomic practices, better irrigation facilities, use of the required quantity of fertilizer at the appropriate time, comprehensive disease and pest management and regular development of improved varieties are the necessary inputs required for improving sugarcane production and productivity.

Nowadays in many parts of the world, sugarcane farmers are confronted with problems such as low cane yields due to poor quality seedcane, caused by diseases and pest contamination, inadequate seedcane harvesting management, low fertilizer inputs, lack of proper irrigation facilities, untimely harvests and several other local constraints.

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Drip irrigation

Since its introduction in the 1970's drip Irrigation for sugarcane has increasingly gained popularity.

Nowadays drip irrigation is known as the most precise, efficient and practical method of delivering water and nutrients to crops. It allows growers to maximize productivity and minimize the use of resources, resulting in significantly higher ROI compared with any other irrigation method.

6 key points why growing sugarcane with drip irrigation contributes to the highest ROI:

- Significantly higher yield* of higher quality plant with higher sucrose content;
- Larger number of ratoons from each planting cycle;
- Considerably lower water use (up to 50%*);
- Enhanced land usage (22% more than center pivot);
- Reduced labor costs (simple to operate);
- Saving in fertilizer (Drip Nutrigation™ precision improves fertilizer use efficiency by 25 to 30%).

*Compared with the global average yield of 59.4 ton/ha (FAO statistics - 2012), cane tonnage at harvest under drip irrigation and Nutrigation™ can vary between 120 and 190 ton/ha.
(Statistical data based on case studies. Individual results are dependent on the site’s specific conditions.)

Sugarcane markets

Sugar

On average, 70-85% of all world sugar comes from sugarcane - most of the rest being derived from sugar beet.

The world's largest sugar consumers are India, the EU, China, Brazil and the USA, with a combined use of around 70 million tons of sugar/annum - almost 50% of the world’s total consumption.

Global per capita consumption now stands at around 24 kg/person/year and continues to expand by 1.5-2.0% per person per year.

Developing countries - particularly in Asia - are expected to be primary sources for future demand. Most of this will be locally produced.

International trade of sugar is heavily influenced by agreements that allow preferential access to higher priced markets such as the USA and EU.

Top exporters of raw sugar are Brazil, followed by Australia and Thailand. Russia, the EU and USA are the three main importing regions.

Ethanol from sugar

Sugarcane is widely regarded as one of the most efficient sources of biomass for bio-fuel.

Ethanol yields per unit area from sugarcane are at least double that produced from wheat or maize.

The global average production of ethanol is 80-85 liters per metric ton of sugarcane, depending on the sugar content.

Brazil has achieved very high levels of ethanol productivity from sugarcane. A typical sugarcane mill in Brazil crushes 2 million tons of cane from 30,000 ha of farmed land and produces 200 million liters of ethanol a year.

Brazil’s total ethanol production from sugarcane is over 31 billion liters/year with over 80% being used in the transport sector, mainly for domestic consumption and sold as pure ethanol or blended with gasoline.

INTRODUCTION

The USA is another significant producer of bioethanol, producing around 50 billion liters/year from maize. European bio-ethanol production stands at around 5 billion liters; China currently produces around 2.5 billion liters per year.

The use of sugarcane for ethanol does not result in a significant net emission of greenhouse gasses. This is because carbon dioxide released from the burning of ethanol balances that absorbed by photosynthesis during crop growth.

The direct consumption of fossil fuels during the ethanol production process is limited to transportation, harvesting and the use of agronomic inputs including fertilizers.

However, even taking this into account, the greenhouse gas emissions balance from sugarcane is very favorable compared with other crops.

In comparison to ethanol from maize, wheat, sugar beet or sorghum, sugarcane-produced ethanol has a higher net energy ratio and a lower level of CO_2 emissions.

Furthermore, burning bagasse (the fibrous residue left after crushing) to produce power enables the production of ethanol from sugarcane without the need of any external source of energy.

Indeed, it is estimated that once bagasse is fully utilized across all of Brazil's bioethanol plants, this could supply 13% of Brazil's energy.

While it could be argued that fuel production reduces the amount of land available to produce food, current bio-ethanol production from crops worldwide occupies 10 million ha - less than 1% of the world's arable land.

By-products

Sugarcane is a highly exploitable crop that also provides a series of added-value products that are extractable during production in the sugar mill.

Bagasse - green energy

Bagasse is the residue left after the juice has been extracted from the cane stalks. It is a solid fibrous material that is composed of around 46 to 53% fiber and 45 to 51% moisture. The quantity of bagasse varies between 25 to 30% by weight of cane. Thus around 250 to 300 kg of bagasse are obtainable from 1 metric ton of sugarcane processed. This bagasse is normally burnt to produce all the energy requirements of the sugar factory in a process called cogeneration.* In fact, the gross calorific value of dry bagasse is around 19,230 kJ/kg, while its net calorific value is around 17,760 kJ/kg. Bagasse is therefore a very valuable renewable source of energy.

*Cogeneration or combined heat and power (CHP) is the use of a heat engine to simultaneously generate electricity and usable heat. Cogeneration is a thermodynamically efficient use of fuel.

Products extractable from bagasse:

- Animal feed
- Board
- Compost
- Paper
- Poultry litter
- Xylitol

Molasses

When the cane juice has been processed to remove the sugar crystals, there remains a thick, dark brown liquid or syrup that is called molasses. This molasses still contains around 34% of sucrose, 11% of reducing sugars (fructose, glucose) and many minerals. It can therefore be used as animal feed, for the culture of yeast, the manufacture of ethanol or rum or other alcohols and many of the sucrose-based co-products, such as acetic acid and other acids.

INTRODUCTION

Products extractable from molasses:

- Animal feed
- Glycerin
- Inositol
- Rum
- Vinegar
- Lactic acid
- Succinic acid
- Glutamic acid
- Aconitic acid
- Kojic acid
- Single-cell proteins

Press mud

Sugarcane press mud (filter cake) is the residue of the filtration of sugarcane juice at the mill. The clarification process separates the juice into a clear juice that rises to the top and goes to manufacture, and a mud that collects at the bottom. The mud is then filtered to separate the suspended matter, which includes insoluble salts and fine bagasse.

Products extractable from press mud:

- Animal feed
- Compost
- Fertilizer
- Waxes and fats

Vinasse

Vinasse is the main by-product of ethanol production in sugar mills. It contains 93% water and 7% solids, including high levels of salts (up to 80,000 mg/L) and organic material (up to 64,000 mg/L). Vinasse has high concentrations of potassium, calcium, magnesium, sulphur and nitrogen. In Brazil, approximately 230 million m^3 of vinasse are produced every year (Unica Data, 2011/2012).

Because of its large volume, the disposal of this effluent causes environmental concerns. Studies have shown that the impact of vinasse infiltration into soil and groundwater resources includes salinisation and rising concentrations of nitrates, nitrites, ammonia, magnesium, phosphate, aluminium, iron, manganese and chloride (Pereira and Pereira, 2008).

Recycling vinasse as a fertiliser through the drip irrigation system (Nutrigation™) has been shown to be the most environmentally safe method of vinasse removal. It is also the most economical method, reducing the amount of fertilizer that needs be applied.

Other by-products extractable from raw sugar:

- Dextran
- Epoxy polymers

Sugarcane quality assessment

Sugar yield depends on cane tonnage, sugar content of the cane and the cane quality.

It is important that the cane is harvested at the most suitable moment, when the economic optimum of recoverable sugar per area is reached.

Cane tonnage at harvest with best management practices under drip irrigation and Nutrigation™ can vary between 120 and 190 ton/ha, depending particularly on the length of the total growing period and whether it is a plant or a ratoon crop.

Toward maturity, vegetative growth is reduced and the sugar content of the cane increases greatly. Sugar content at harvest is usually between 10 and 16% of the weight of the fresh cane. Sugar content seems to decrease slightly with increased cane yields.

Luxurious growth should be avoided during cane ripening; this can be achieved by low temperature, low nitrogen level and restricted water supply.

With respect to juice purity, low minimum temperatures positively affect this factor during a period of several weeks before harvest.

Generally the sucrose content in the harvested sugarcane varies between 10 and 16%.

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Sugar market requirements

Sugarcane characteristics required by the industry

- Cleanliness and freshness, low levels of leaves, tops and soil;
- Low fiber levels - the higher the fiber, the larger the loss of sucrose in the bagasse;
- High level of total soluble solids in the juice (°Brix);
- High sucrose levels, often expressed as pol (short for polarization) in the processed juice, combined with low level of reducing sugars;
- The value of the crop is determined by yield of sugar;
- Sugar content of sugarcane ranging between 10% and 16%.
  Growers need to optimize sugar levels without compromising cane yield.

Payment is linked to cane quality as tested by the mill, based on representative cane samples.

Tests include the assessment of the following characteristics:

- **°Brix** (%) is the content of soluble solids of the first stage juice processed by the plant and assessed by refractometry tests;
- **Pol** (% sucrose) is the sucrose content in the juice. Sugar contains about 98% sucrose (98 degrees pol). It is determined by using a polarimeter or a sucrolyser.
- **Purity** is the percentage of sucrose in the total solids in the juice.
  Higher purity is the result of higher sucrose content in the total solids present in the juice.
- **Fiber content** - the percentage of fiber in cane is determined by the analysis of cane sampled upon delivery.

Data in this chapter, courtesy of Yara's Sugarcane Plantmaster™.

ECONOMIC ANALYSIS

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ECONOMIC ANALYSIS

The initial investment in a sugarcane cultivation project can reach thousands of USD per hectare, and is comprised of various factors influencing the net income.

The initial investment can affect the project's profitability for a period as long as 20 years; thus, understanding all the influencing factors is a precondition for maximizing the net income.

This chapter presents the reader with the main factors to consider when evaluating the profitability of investing in a certain irrigation system and the weight of each factor in the overall calculation.

When establishing a drip irrigation system there are 2 types of projects:

- **Greenfield** is a new sugarcane project established from scratch.
- **Brownfield** is an upgrade or modification of an existing sugarcane project.

In both cases total budgeting (presented below) should be implemented in order to estimate the returns and profit of the farm as accurately as possible.

EXAMPLE

In the case of converting a farm from center pivot to drip irrigation: It is known that drip irrigation is 22% more efficient than center pivot in land exploitation. However, this advantage and its actual effect on the CAPEX and OPEX are revealed only by means of total farm budgeting.

For simplicity, this chapter refers to:

- The price of a ton of sugarcane before processing.
  Market requirements differ according to country and end product. Different markets use different methods to assess the price paid for a ton of sugarcane, considering different parameters such as sucrose content, fiber level, etc. It is recommended to be familiar with the pricing method of the local sugarcane mill in advance.
- A project life expectancy of 20 years.

Farm budgeting

Farm budgeting is a process of estimating costs, returns and net profit of a farm.
Planning and budgeting go hand in hand.
The budget helps to evaluate alternative plans and select the one that is most profitable.

There are two types (methods) of farm budgeting.

Partial budgeting refers to estimating the costs and returns for only a part of the farm (for example: the irrigation system).
Because many factors affecting the total profitability are ignored, this may lead to wrong estimates, such as:

- Trying to estimate the payback period without taking into consideration the yield.
- Trying to compare two proposed irrigation systems without taking into consideration water limitations.

Total budgeting (Complete budgeting) refers to preparing a budget for the farm as a whole. Total budgeting takes into consideration all the aspects of growing sugarcane (See Income, CAPEX and OPEX, page 13).

Total budgeting can be specifically defined as an estimation of the probable income and expenditure of the farm as a single unit.
Total budgeting is required when a farm plan is prepared for a new farm or when drastic changes are suggested in the plan of the existing farm.
Total budgeting can be prepared for the short run (annual budget) and for the long run.

ECONOMIC ANALYSIS

There is no correlation between the size of the initial investment and the net profit.
The OPEX component along the growing period has a considerable impact on the net profit.
A realistic estimate of the net profit is possible only when taking into consideration the income, the CAPEX and the OPEX factors.

The choice of irrigation method has a substantial effect on the initial investment and on the day-to-day operating expenditure (see Choice of Irrigation Method, page 15).

Income

Money received in exchange for sugarcane supplied to the mill (unlike "earnings," which refers to the remaining revenues after all expenses and taxes have been paid).

The main factors considered when calculating the income of a sugarcane farm are:

- Annual yield.
- Cane quality (in terms of sucrose content and/or fiber level).

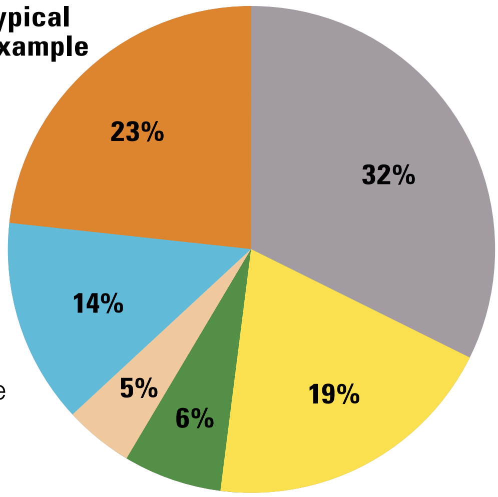
CAPEX (capital expenditure)

Expenditures that create future benefits. A capital expenditure is incurred when a farm spends money to buy equipment or purchase land, assets with a useful life extending beyond the taxable year that add to the value of the farm.

The main factors considered when calculating the CAPEX of a sugarcane farm are:

- Cost of irrigation system
- Crop establishment
- Cost of bulk water supply:
  - Distance of the water source from the field
  - Type of water source - surface water; groundwater; etc.
  - Differences in level between the water source and the field
- Cost of land
- Machinery
- Site development: ■ Field leveling ■ Road surfacing ■ Drainage ■ Soil preparation ■ Buildings

Typical example



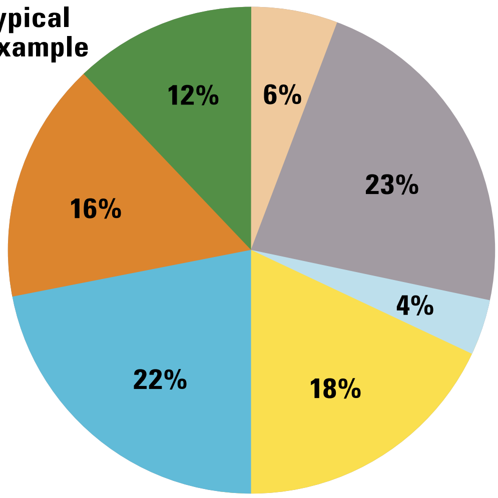
OPEX (operating expenditure)

The ongoing cost for day-to-day running of a business or a system.

The main factors considered when calculating the OPEX of a sugarcane farm are:

- Energy
- Fertilizers and chemicals
- Water
- Harvesting
- Cane haulage from field
- Human resource: ■ Agricultural workforce ■ Management and administration ■ Technical personnel
- Maintenance: ■ of the irrigation system ■ of the infrastructure ■ of the agro-machinery ■ of the buildings

Typical example



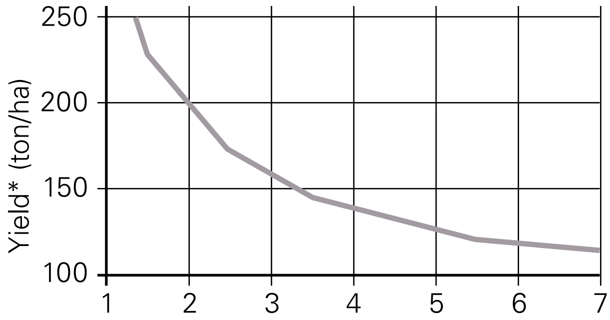
ECONOMIC ANALYSIS

Sensitivity analysis

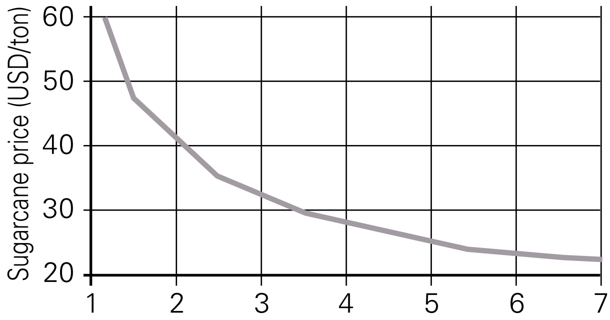
An important part of the economic analysis, the sensitivity analysis is performed to determine how different values of an independent variable will impact a particular dependent variable under a given set of assumptions.

EXAMPLE

How a change in yield per hectare of sugarcane will affect the length of the payback period



How a change in sugarcane price will affect the length of the payback period



*Typical to growing with drip irrigation. **The payback period for the drip irrigation system.

Financial Definitions

Cost-per-ton sugarcane produced (USD)

This figure is not a pure/standard financial term.

It is a simple calculation of the average cost of production that can be used to give an indication of how much it costs to produce one unit of sugarcane including expenses, financing and depreciation.

The formula used is: **(CAPEX + OPEX + Finance) / Total yield = Cost-per-ton sugarcane produced**

The lower the cost per unit of yield produced, the better.

IRR - Internal Rate of Return

The internal rate of return (IRR) is the discount factor (see below) at which the NPV equals zero.

It is used to analyze the maximum interest rate at which the project is profitable (the highest interest rate that a project can afford to pay).

A higher IRR is better, as it means the project generates a higher rate of return.

NPV - Net Present Value

NPV is the most commonly used method for evaluating the profitability of a project.

The method discounts all cash flows (inflows & outflows) with the cost of capital (equal in this model to the interest rate or to the cost of financing if the financing option is used) to the present value.

Higher NPV means the project is more profitable.

Payback period

A project has a negative cash flow at the beginning of the project (due to an investment), and a positive cash flow at a later stage once income exceeds expenses.

The formula analyzes when the present value of the cash flow will become positive and the investment will be covered. A shorter period is better and means faster return on investment.

Discount factor

The interest rate used in discounted cash-flow analyses to determine the present value of future cash flows.

The discount rate takes into account the time value of money (the idea that money available now is worth more than the same amount of money available in the future because it could be earning interest) and the risk or uncertainty of the anticipated future cash flows.

In this model, the discounted factor is equal to the annual interest rate paid on loans.

CHOICE OF IRRIGATION METHOD

CHOICE OF IRRIGATION METHOD

Factors influencing the selection of an irrigation method

The choice of an irrigation method is influenced by many factors. The impact each of these factors has on the project financing is critical for ROI (return on investment) calculation.

The tables below present the major factors to be considered. The influence each factor has on the selection of each irrigation method is ranked based on years of experience and data gathered from a multitude of different projects around the globe.

The factors to consider are presented in two categories:

- **Primary factors** that have a major influence on the profitability of any irrigation project.
- **Secondary factors** that can each have a significant influence on the profitability of the project, depending on the specific characteristics of the project, the local conditions and the growers' goals.

Primary factors

		Furrow	Center pivot	Solid set sprinklers	Drip
Costs	Initial investment (green field)	⊖ ⊖	⊖	⊖	⊖ ⊖ ⊖
	Operating costs	⊖	⊖ ⊖	⊖ ⊖ ⊖	⊖
Product	Yield and quality	⊕	⊕ ⊕	⊕	⊕ ⊕ ⊕
Resources	Electrical requirements	⊖	⊖ ⊖	⊖ ⊖ ⊖	⊖
	Labor skill requirements	⊖	⊖ ⊖	⊖	⊖ ⊖
	Labor costs	⊖ ⊖	⊖	⊖ ⊖	⊖
	Water pumping costs	⊖	⊖ ⊖	⊖ ⊖ ⊖	⊖
	Water supply limitations	⊖ ⊖ ⊖	⊖ ⊖	⊖ ⊖ ⊖	⊖
Water quality	High TSS (total suspended solids) water	⊖	⊖	⊖	⊖ ⊖ ⊖
	Hard water (high carbonate content)	⊖	⊖ ⊖	⊖ ⊖	⊖ ⊖
	Saline water	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖
	Filtration requirements	⊖	⊖	⊖ ⊖	⊖ ⊖ ⊖
Soil	Low WHC (water holding capacity) soil	⊖ ⊖ ⊖	⊖ ⊖	⊖ ⊖	⊖
	Heavy clay soil	⊖	⊖ ⊖	⊖ ⊖	⊖
	Saline soil	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖

Secondary factors

		Furrow	Center pivot	Solid set sprinklers	Drip
The irrigation system	Distribution efficiency, accuracy and uniformity	⊕	⊕ ⊕	⊕ ⊕	⊕ ⊕ ⊕
	System downtime due to common malfunctions	⊖	⊖ ⊖ ⊖	⊖	⊖
	System susceptibility to theft and vandalism	⊖	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖ ⊖
Field coverage	Coverage of field area	⊕	⊕ ⊕	⊕ ⊕	⊕ ⊕ ⊕
	Odd shaped fields	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖ ⊖	⊖
	Small plot size (< 20 ha)	⊖	⊖ ⊖ ⊖	⊖	⊖
	Large plot size (> 30 ha)	⊖	⊖	⊖ ⊖	⊖
Climate	High winds	⊖	⊖ ⊖	⊖ ⊖ ⊖	⊖
	High evaporation	⊖ ⊖ ⊖	⊖ ⊖	⊖ ⊖	⊖
Topography	Steep/undulating topography	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖ ⊖	⊖
	Erodible soil with steep topography	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖ ⊖ ⊖	⊖
Nutrigation™	Automatic Nutrigation™ compatibility	⊕	⊕ ⊕	⊕ ⊕ ⊕	⊕ ⊕ ⊕
	Nutrigation™ efficiency, accuracy and flexibility	⊕	⊕	⊕ ⊕	⊕ ⊕ ⊕
Control	Automation potential	⊕	⊕ ⊕	⊕ ⊕	⊕ ⊕ ⊕
	Crop management technology	⊕	⊕ ⊕	⊕	⊕ ⊕ ⊕
Crop protection	Foliage wetting prevention	⊕ ⊕ ⊕	⊕	⊕	⊕ ⊕ ⊕
	Weed and pest control compatibility	⊕ ⊕	⊕	⊕	⊕ ⊕ ⊕

The factor has: ⊕ a positive or ⊖ a negative influence on selection of the method.

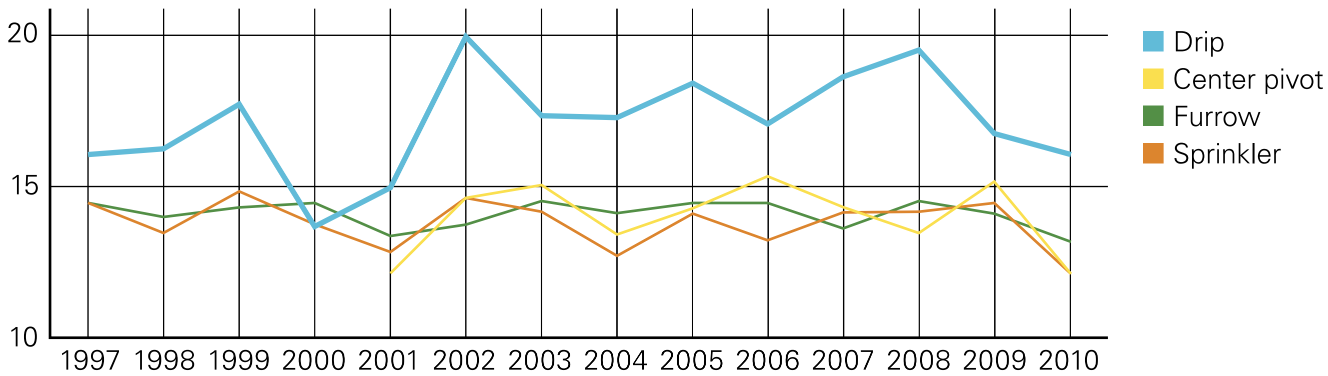
CHOICE OF IRRIGATION METHOD

Yield and quality under various irrigation methods

At the bottom line, the factor that influences the choice of an irrigation method most is the profit, and no single factor impacts the profit as much as the yield and quality of the harvested sugarcane do. The example below demonstrates the sucrose yield achieved with different irrigation methods in the same farm, under the same overall conditions (see the Project Case Study, page 64).

EXAMPLE

Sucrose yield of Mhlume estate, Swaziland by irrigation type:
(Sucrose ton/ha)



(Source: Ndlovu*)

Efficiency comparison of irrigation systems

The cost of water is a major factor in the comparison. Where water charges are incorporated into the analysis, the more water-efficient technologies become more attractive, especially where water supply is limited (Source: Qureshi** et al., 2001).

Crop water requirement (mm/year)	Rain (mm/year)	Rain efficiency (%)	Available rain (mm/year)	Irrigation requirement (mm/year)	Furrow	Solid set sprinklers	Center pivot	Drip
					Irrigation efficiency (%)			
					60	80	85	95
					Actual application of water (mm/year)			
2000	250	70	175	1825	3041	2281	2147	1921
	750		525	1475	2458	1843	1735	1552
	1250		875	1125	1875	1406	1323	1184
	1750		1225	775	1291	968	911	815

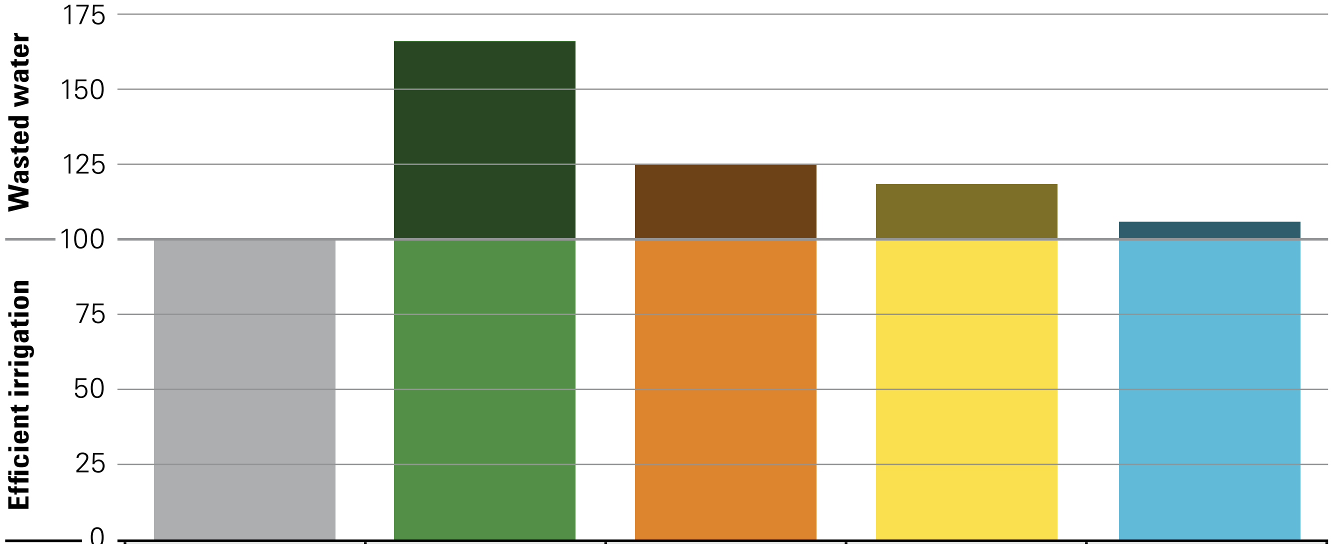
NOTE
As the world population grows, water availability and cost become increasingly major considerations.

The efficiency of an irrigation method determines the amount of water wasted when irrigating. While an inefficient method, such as furrow, might spend up to 67% more water for supplying the irrigation requirement, a highly efficient method, such as drip, will supply the irrigation requirement with a surplus of only 5%!

*Dr. Leonard Sive Ndlovu, the Royal Swaziland Sugarcane Corporation.
** Muhammad Ejaz Qureshi - PhD Resource Economics & Environmental Management, CSIRO Ecosystem Sciences, Australia.

CHOICE OF IRRIGATION METHOD

Actual application of water (%)



	Irrigation requirement	Furrow	Solid set sprinklers	Center pivot	Drip
(%)	100	167	125	118	105

Labor requirements for different irrigation systems

Labor requirements differ with irrigation method and may be important in choosing the most suitable method.

	Furrow	Solid set sprinklers	Center pivot	Drip
Labor requirement (Labor days/100 ha)	72	91	12*	12*

*SDI (subsurface drip irrigation) and center pivot irrigation system operation and maintenance require professional management and trained technicians.

Power consumption comparisons for a typical irrigation block

A critical factor in choosing an irrigation system is its energy requirement. The cost of pumping from water source to field edge and field edge to infield should be quantified. This will give a complete picture, and enable more accurate comparisons to be made when choosing between irrigation systems. Power consumption (kWh/ha/year) should be used as the principal comparison indicator.

The power consumption calulated here is based on the efficiency comparison of irrigation systems table (see previous page) with 1250 mm/year rain (3rd row).

	Furrow	Solid set sprinklers	Center pivot	Drip
Power consumption (kW/ha/year)	1202	3305	2544	2024

Calculation notes:

- Pump efficiency is assumed at 65%.
- All systems were taken as 1 hectare for comparison purposes.
- Assumed flow rate (m^3/ha/h): furrow - 100, solid set sprinklers - 70, center pivot - 36, drip - 10.
- Assumed pressure (bar): furrow - 1.5, solid set sprinklers - 5.5, center pivot - 4.5, drip - 4.0.

Comments

- The SDI system has the best agronomic performance (Source: Armitage* et al., 2008).
- Compared with center pivot, SDI can generate more gross revenue by having a higher percentage of irrigated land in a given field (influence of shape) (Source: Lamm** et al., 2002).
- Furrow has the greatest risk of deep drainage losses and may be contributing to rising water tables (Source: Qureshi*** et al., 2001).

All the factors mentioned in this chapter have major impact on the eventual selection of the irrigation system. However, a well-substantiated financial analysis must be carried out in order to select the most effective and efficient irrigation system for a specific project (see Economic analysis, page 11).

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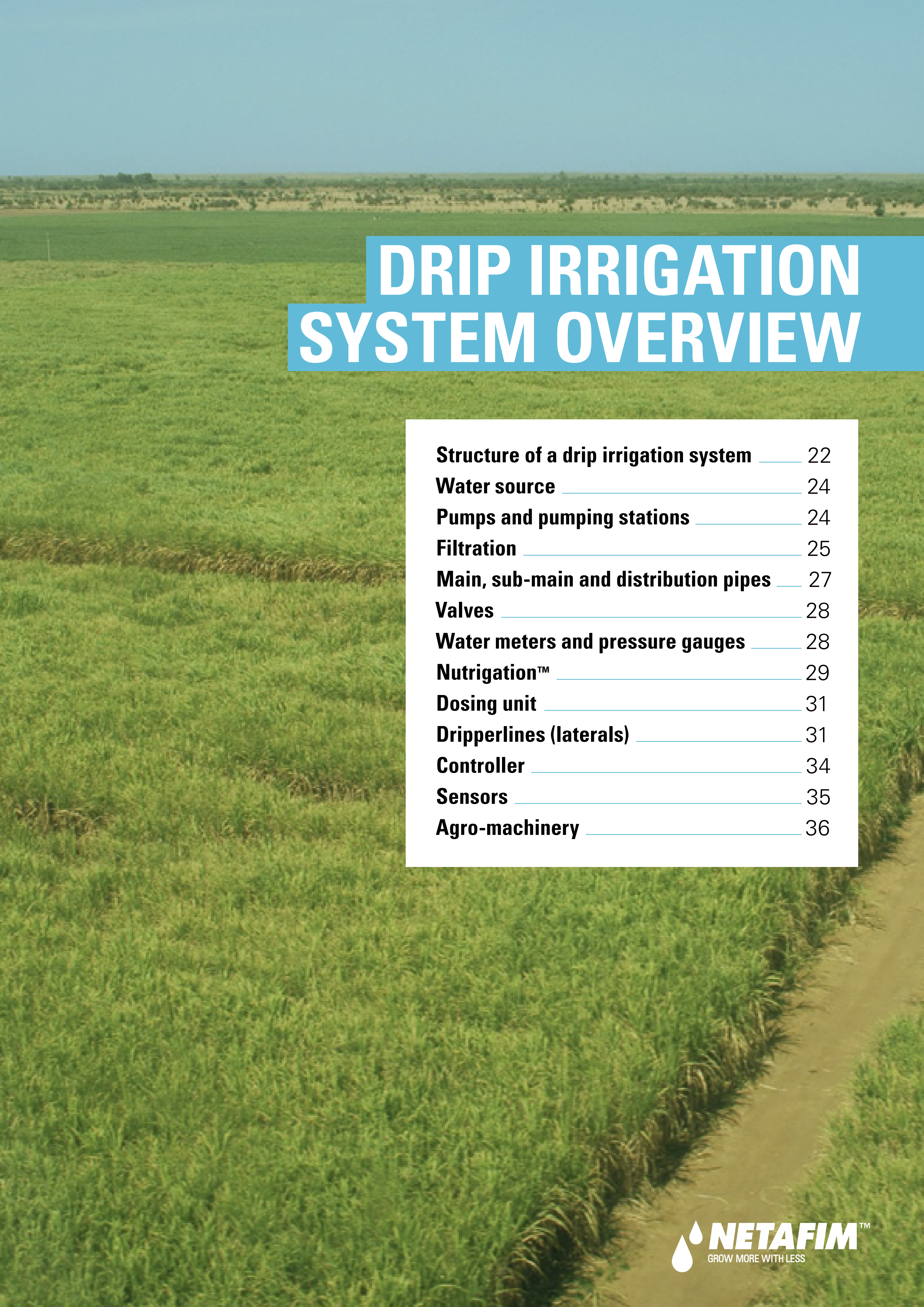
**Freddie Lamm - PhD Agricultural Engineering, Kansas State University, US.
***Muhammad Ejaz Qureshi - PhD Resource Economics & Environmental Management, CSIRO Ecosystem Sciences, Australia.



DRIP IRRIGATION SYSTEM OVERVIEW

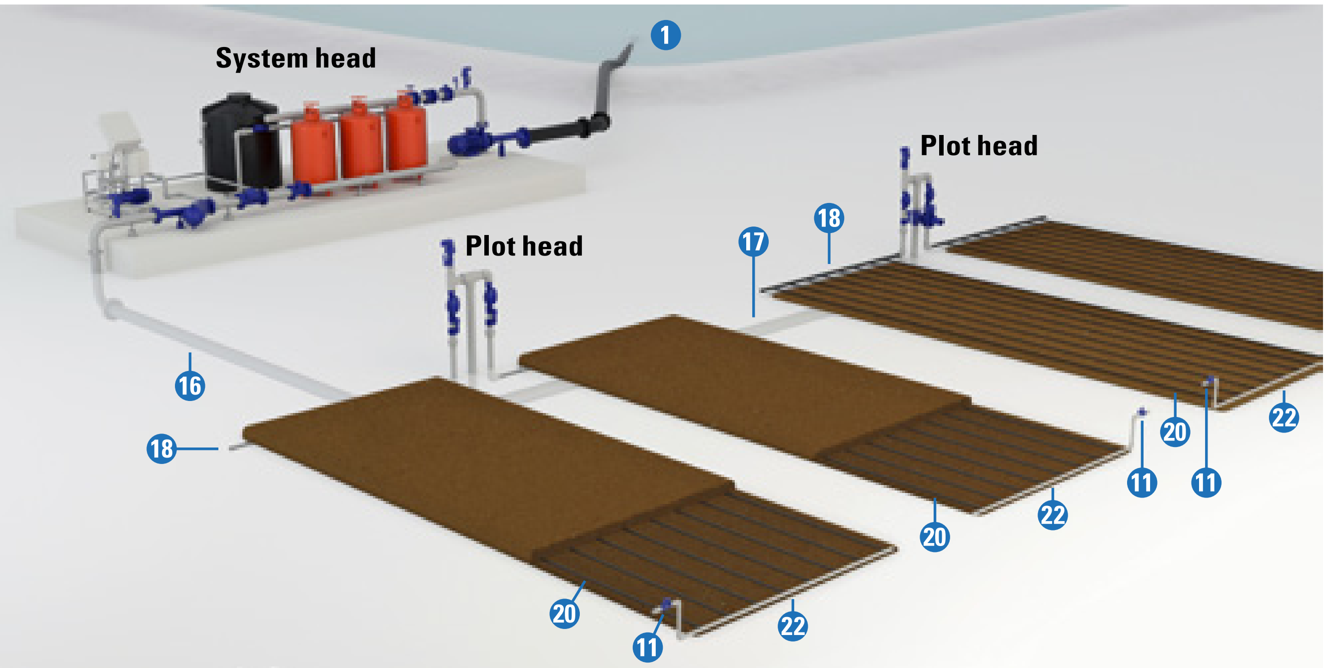
NETAFIM™
GROW MORE WITH LESS

DRIP IRRIGATION SYSTEM OVERVIEW

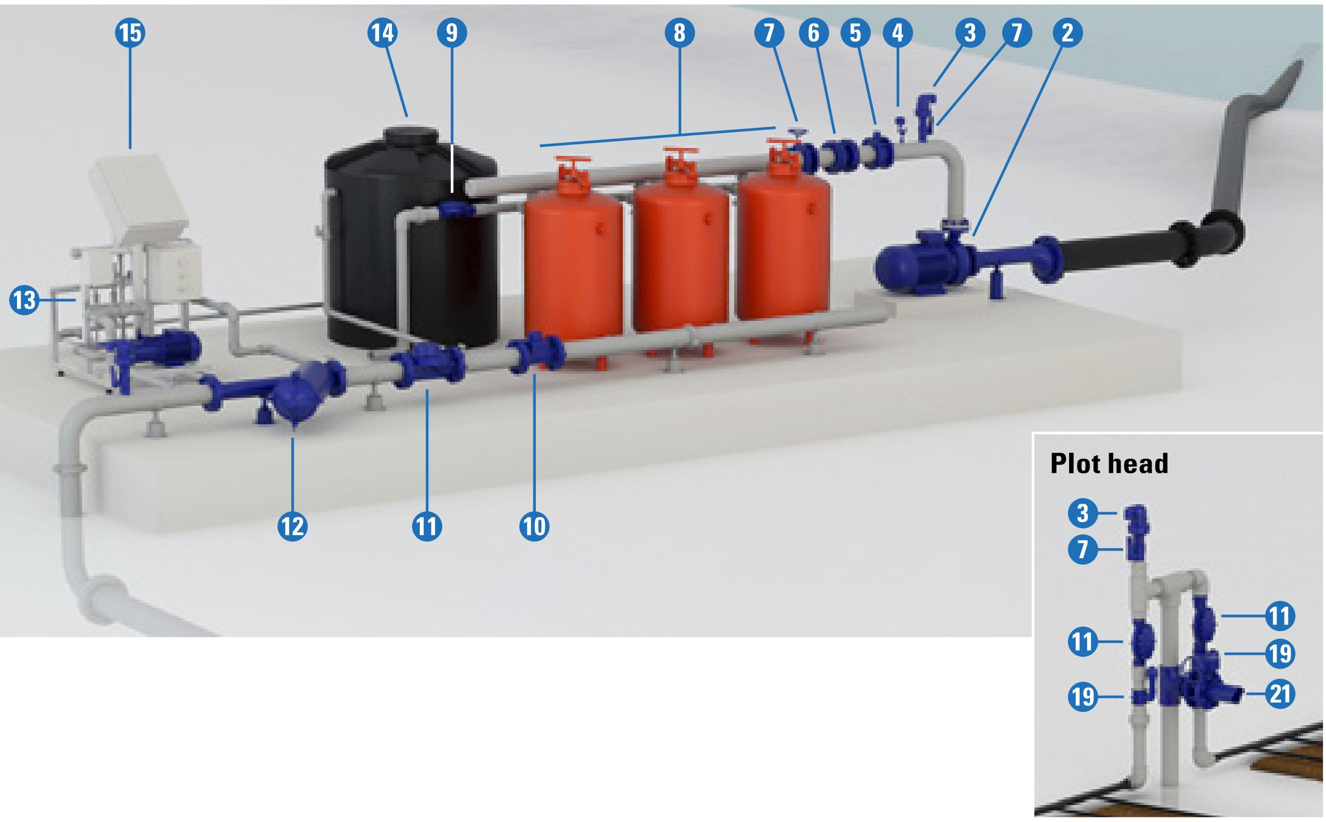
A drip irrigation system comprises many components, each of them playing an important part in the operation of the system.

The aim of this chapter is to provide a concise overview of the drip irrigation system for cultivation of sugarcane, its components, their functions and properties (for further reading see http://www.netafim.com/crop/sugarcane).

Structure of the drip irrigation system

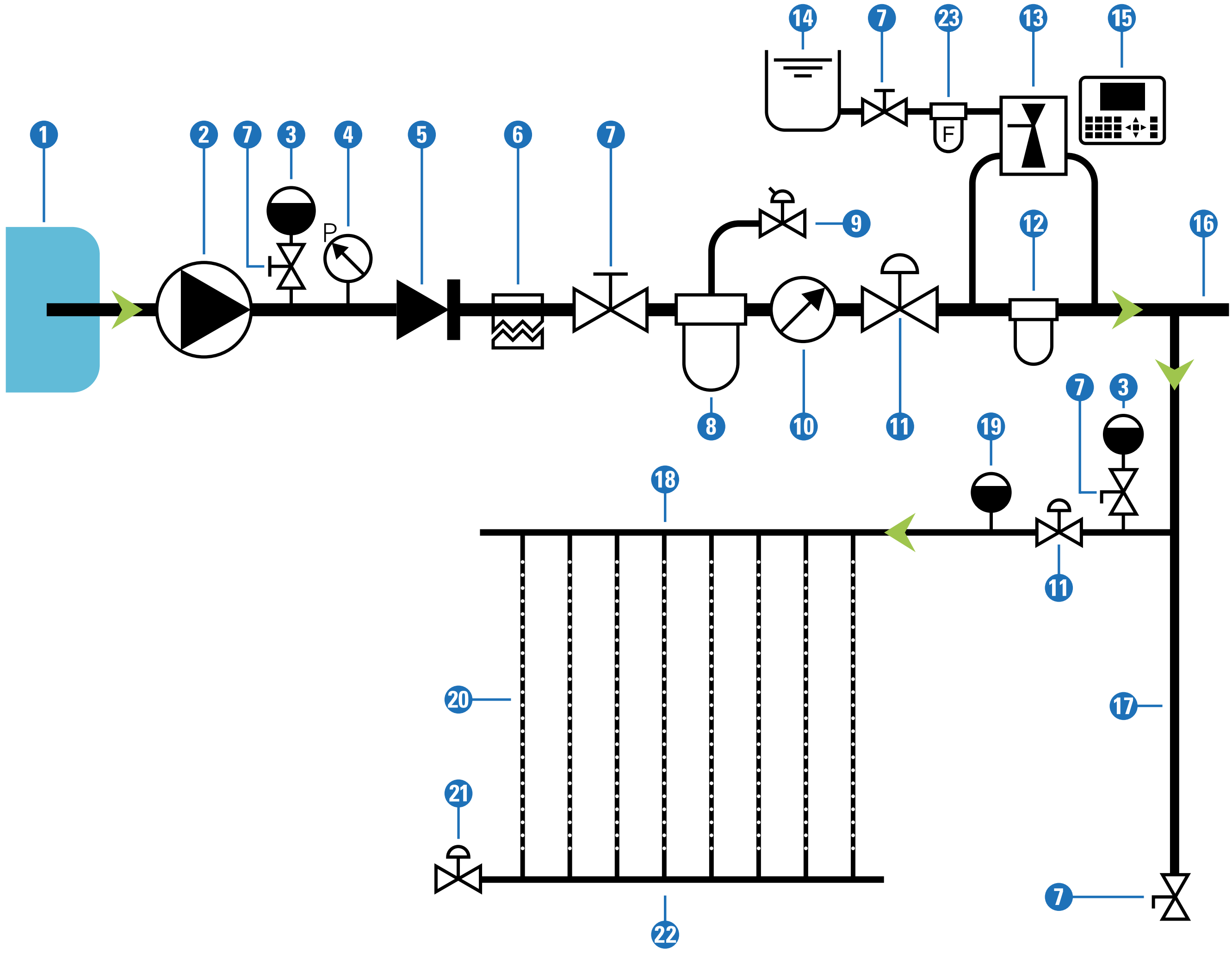


System head



DRIP IRRIGATION SYSTEM OVERVIEW

Schematic diagram



1 Water source
2 Pumping station
3 Air valve
4 Pressure gauge
5 Check valve
6 Shock absorber
7 Manual valve
8 Main filtration unit
9 Main filtration automatic drainage valve
10 Water meter
11 Hydraulic valve
12 Secondary filtration unit
13 Dosing unit
14 Fertilizer tank
15 Irrigation controller
16 Main line
17 Sub-main line
18 Distribution line
19 Kinetic valve (vacuum breaker)
20 Dripperline
21 Flushing valve
22 Flushing manifold
23 Fertilizer filter

DRIP IRRIGATION SYSTEM OVERVIEW

Water source

There are basically two main types of water sources:

Surface water tends to introduce biological hazards. If waste waters, mill effluents such as vinasse and/or recycled waters are being considered as a source, quality and clogging potential will vary depending upon the extent of treatment.

Groundwater may appear to the naked eye as being of higher quality than surface water. However, iron and manganese levels should be measured, as high levels lead to dripper clogging, and treatment may be required. High nutrient levels in the ground water may cause nutrient imbalances when nutrigating; e.g., high iron levels may precipitate with phosphorus, making it less available.

For a list of substances usually present in source water see Water quality, page 50.

Pumps and pumping stations

Unless the water source is at a higher elevation than the field and supplies adequate flow rate and pressure (gravitational pressure*), a pump will be needed to push water from the source through the pipes and drippers.

Typically, a drip irrigation system requires a pressure of at least 3 bars (43.5 psi), i.e., the water source should be at an elevation of at least 30 meters (98.5 feet) higher than the field.

Most irrigation systems include pumps as an integral part of the drip irrigation system.

***Gravitational pressure** (also known as hydrostatic pressure) is the pressure at a point in a fluid at rest due to the weight of the fluid above it. If the water source is at a higher elevation than the drippers in the field, the elevation difference between them will determine the gravitational pressure in the system (e.g., if the water level in a tank is 10 meters above the elevation of the pump's axis, the gravitational pressure is 10 meters = 1 bar = 14.5 psi).

Selecting a pump for an irrigation system requires an understanding of the water conditions and local system requirements.

Poor pump selection can lead to high operating costs and shortened pump life; this in turn impacts on the performance and reliability of the whole irrigation system.

In selecting a pump site, it is necessary to consider a range of factors, including availability of power, proximity to the development site and water quality issues.

Filtration

Filtration is critical in any drip irrigation system. Effective filtration is essential for proper irrigation system operation and long-term performance, as it prevents the irrigation water from clogging the drippers.

Water quality

The concept "water quality" refers to the variety and concentration of the dissolved and suspended components in the water.

Water requirements for drip irrigation

The quality of water for irrigation is related to the parameters required to maintain the crop's health and the integrity of the irrigation system. Every type of pressurized irrigation system requires attention to the water quality to avoid clogging of the irrigation components and to enable regular long-term irrigation according to the irrigation program.

Water quality dictates filtration requirements, chemical injection requirements, and management of the irrigation systems to prevent dripper clogging.

Causes of dripper clogging in systems may be chemical (precipitates or scale), physical (grit or particulates such as sand and sediment) or biological (such as algae or bacteria).

The water's chemical characteristics are influenced by the variety and concentration of the substances dissolved in it. These dissolved substances include ions of dissolved salts such as chloride, sodium and nutrients (nitrogen, phosphorous, potassium and others). Calcium and magnesium influence the hardness of the water; iron and manganese are liable to be found either dissolved or as a residue, along with other dissolved organic compounds and even poisonous substances.

The biological characteristics of the water quality include a variety of living organisms such as micro-organisms, including bacteria, viruses, single-cell organisms, algae and zooplankton, which develop in open water along with creatures developing within the water transport system itself.

The water quality is expressed by the physical conditions and the variety and concentration of its constituents.

The quality of the water is determined by a wide variety of parameters (measured or calculated) affecting the crop, the soil and the irrigation system. Some of them are listed below:

- **EC** (electrical conductivity)
- **pH** (level of acidity or alkalinity)
- **Ca** (calcium - hardness of the water)
- **Mg** (magnesium)
- **Na** (sodium)
- **HCO_3** (bicarbonate)
- **CO_3** (carbonate)
- **Alk** (alkalinity)
- **Cl** (chloride)
- **SO_4** (sulfate)
- **Fe** (iron)
- **Mn** (manganese)
- **TSS** (total suspended solids)
- **TDS** (total dissolved solids)
- **Turbidity**
- **K** (potassium)
- **PO_4** (phosphate)
- **$N\text{-}NH_4$** (nitrogen-ammonium)
- **$N\text{-}NH_3$** (nitrogen-nitrate)
- **B** (boron)
- **Algae** and **Chlorophyll**
- **Zooplankton**
- **BOD** (biochemical oxygen demand*)
- **COD** (chemical oxygen demand*)
- **VSS** (volatile suspended solids*)

*When waste water, mill effluents such as vinasse and/or recycled water are used.

Water analysis

A water analysis is necessary in order to select the appropriate type of filtration system, to prescribe a suitable maintenance program, to select the type of dripperlines and to prescribe an appropriate Nutrigation™ plan (see Water analysis, page 50).

DRIP IRRIGATION SYSTEM OVERVIEW

Types of filters

The types of filters used most often in drip irrigation systems are:

Media filters (gravel) are used mainly for surface water sources and especially for hard water sources. They consist of a metal or plastic enclosure containing small gravel, which traps the dirt. This filter includes a flushing system for washing the gravel and returning the dirt to the water source.

Disk filters are used with surface water systems, wells or municipal water sources. These filters are comprised of a series of grooved plastic disks stacked together with a total equivalent screen size ranging from 37 to 400 micron (400 to 40 mesh). These filters enable deep three-dimensional filtering (e.g., entrapment of more particles as water passes through the pores created by the grooves in the surfaces of the filtering disks that are stacked together in the filter).
Because they have more surface area than screen filters do, disk filters are better suited for hard water.

Screen filters are used mainly as primary filters with well or municipal water sources or as secondary filters with surface water systems. A screen filter is comprised of a cylinder with a screen that traps the dirt. This filter is intended for relatively clean water.

Hydrocyclone sand separators are used as a preliminary stage of filtration in the presence of sand or other heavy particles (50 micron or bigger) in the source water. They utilize centrifugal force to separate the particles from the water. The separated material drops down into a tank or reservoir where it can be removed later.
There is no physical barrier to separate out the particles, but such a separator is often used before a filter to first remove the bulk of the contaminant, where the filter does the final cleaning. This type of design reduces the time required to flush and clean the main filter. Each hydrocyclone model has its specific operation flow velocity range, and will not perform outside this range.

Choice of filtration type

The type of filtration to be used should be carefully selected according to the general quality of the irrigation water and the presence of various substances in it, as well as the specific requirements of the irrigation system.

Removal efficiency of particle types in gravel, disc and screen filters

Plugging factor	Filter type		
	Screen	Gravel	Disc
Suspended solids (general)	●●	●●●●	●●●●
Sand (after Hydrocyclone*)	●●	●●●	●●
Silt and clay	●	●●●●	●●
Algae (< 40 micron)	●	●●●●	●●●
Zooplankton	●●●	●●	●●●
Iron and manganese (after oxidization)	●●	●●●●	●●

*Source water containing sand, such as flowing water or well water, usually requires a sand separator to remove sand before it enters the filteration system (see Hydrocyclone sand separator, page 26).

Main, sub-main and distribution pipes

Pipelines carry water through the entire irrigation system, from the pump through the filters, the valves, and onward to the drippers.

The water conveyance system accounts for 30-35% of the total cost of the irrigation system. Thus, the correct selection of piping is of utmost importance.

PVC or PE is the common choice of material for the pipes, although there are situations where pipes made of other materials such as steel or GRP are customary, based on the local conditions.

The correct planning of the water conveyance system in terms of flow rate in the main and sub-main pipes and of the pipes' class are of utmost importance.

The selected pipes should be of sufficient quality to ensure burst-free operation throughout the project's life, but not high in quality as to unnecessarily increase the initial cost of the system.

High flow velocity might lead to water hammer and frequent pipe bursts.

Air release valves should be installed along the pipes and at its end according to the planner's instructions.

Over the last few years, Netafim™ has developed a series of lay-flat pipes for on-ground laying, usable as main and sub-main pipes. Incorporating these pipes in the irrigation system can significantly lower its initial cost, especially where the water conveyance and storage system constitutes a significant portion of the irrigation system total setting-up cost.

For further reading see http://www.netafim.com/crop/sugarcane.

DRIP IRRIGATION SYSTEM OVERVIEW

Valves

In an irrigation system, water flow rate and pressure throughout the system should be precisely controlled to ensure efficient and timely water application; therefore proper selection and placement of valves is critical.

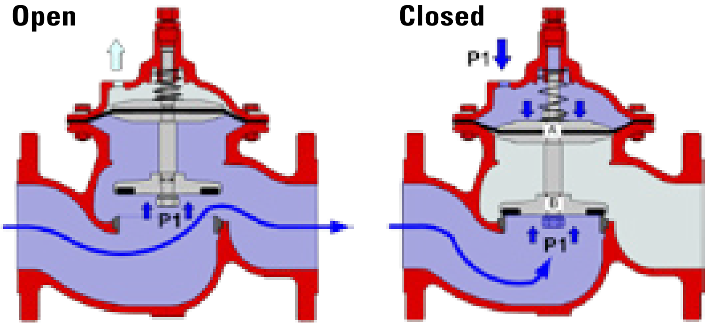
Valves play a key role in controlling pressure, flow and distribution under different conditions to optimize performance, facilitate management, and reduce maintenance requirements.

Hydraulically operated, diaphragm-actuated control valves

These valves serve different purposes according to the specific need in every case by altering the layout of the valve's control loop.

Hydraulically operated valves can serve as:

- Hydraulic control valves
- Pressure-reducing valves (PRV)
- Pressure-relief/sustaining valves
- Pressure-reducing and -sustaining valves
- Pressure-relief valves
- Booster pump control valves
- Surge-anticipating valves



Air valves

Combination air release valve
Evacuates a large volume of air during pipeline filling and network draining and allows efficient release of air pockets from pressurized pipelines.

Kinetic air valve
Evacuates a large volume of air during pipeline filling and network draining.

Water meters and pressure gauges

A drip irrigation system has a water meter and pressure gauges. These monitoring devices are essential for proper system operation.

Water meters

Water meters play an important role in the drip irrigation system. They measure (automatically or manually) the quantity of water supplied to the field as a whole and to the individual plot, and detect any deviation that might occur over time.

Deviations can be of two kinds:
High flow (HF) - usually due to leaks or bursts in the water conveyance system or control valves' malfunction.
Low flow (HF) - usually due to drippers' clogging or control valves' malfunction.

Woltman water meters are commonly used with small diameter pipes and saddle water meters are used with large diameter pipes.

In most cases water meters are installed in the pump room or the irrigation room, although it is also customary to install a water meter at the plot head to monitor the irrigation of the individual plot.

DRIP IRRIGATION SYSTEM OVERVIEW

Water meters should be installed according to accepted standards in order to accurately monitor the water supply.

Installation of a water meter pulse sensor allows monitoring of the water supply to the plot by means of an irrigation controller that can calculate the accumulated quantity of water supplied to the plot over time and issue an alert when deviations occur.

Pressure gauges

Pressure gauges are standard components of drip irrigation systems.

Despite their negligible cost, they provide vital information concerning the irrigation system.

System pressure monitoring is essential in order to keep the irrigation system within its operating range, manage the filters and chemical injectors and detect leaks or clogging.

Nutrigation™

Each crop needs a different range of nutrient elements at every stage of its development.

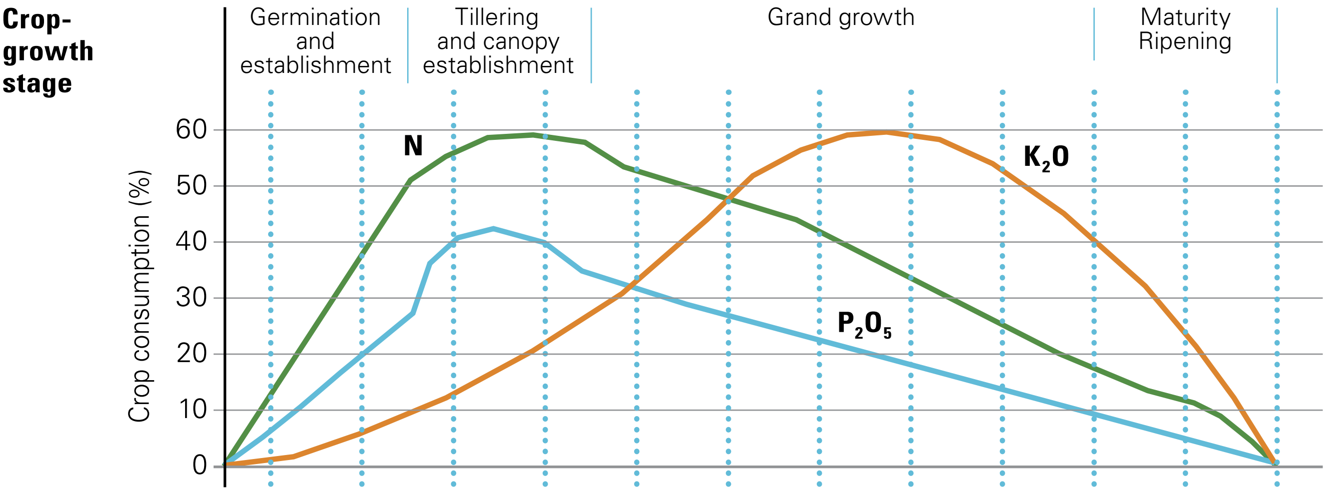
Many plant nutrients can be found in the soil, but they are often unavailable to the plant or in insufficient quantities to sustain high yield. Soil characteristics and climatic conditions can also limit the plant's uptake of nutrients at key growth stages.

Sugarcane is a giant crop that produces a huge quantity of biomass; therefore it generally requires higher amounts of nutrient elements.

A large number of research experiments have clearly demonstrated that production of higher cane and sugar yields on a sustainable basis requires the application of adequate amounts of fertilizer nutrients (i.e., N, P and K) at each crop-growth stage.

Depending on soil conditions, other nutrients may also be necessary. At all times it is essential to keep the correct nutrient balance and form of nutrient to ensure maximum yield potentials are achieved.

Relative requirement of NPK at different crop growth stages of sugarcane



DAP*	30	60	90	120	150	180	210	240	270	300	330	360
Month	1	2	3	4	5	6	7	8	9	10	11	12
Kc**	0.45	0.55	0.65	0.70	0.75	0.80	0.85	0.90	1.05	1.05	1.05	0.60

*DAP = Days after planting. **Kc (Crop coefficient) = the effect of the crop aspects (see Kc, page 47).

EXAMPLE

Nutrtigation™ schedule for a 12-month sugarcane growing season (or ratoon)

DAP	30	60	90	120	150	180	210	240	270	300	330	360
Nutrients to be applied (kg/ha/day)												
N	1.20	1.50		2.00	0.75	-						
P_2O_5	0.10	0.40		1.00	0.30	-						
K_2O	0.20	0.24		0.40	0.75	1.50						

This table is only a guideline. A specific table should be prepared based on local factors (i.e., soil, variety, climate and management).

Nutrigation™ via a drip irrigation system

The most effective way to increase the yield and quality of a crop is by feeding the plant according to its specific, ever-changing needs. This means delivering the right amount of water and nutrients at the right time. Nutrigation™ refers to injection of nutrients for the plant.

Nutrigation™ is the combined application of water and nutrients to a crop - a mix of fertilization and irrigation. It can be adapted to all types of crops.

In drip irrigation, the roots are concentrated in a limited volume of soil. For this reason, during the irrigation season, relatively small quantities of fertilizers should be applied frequently.

In traditional fertilization methods, some of the fertilizer is applied outside the root system and thereby wasted.

Advantages

Increased efficiency of fertilizer application

- Fertilizer application with irrigation water provides a better distribution and greater application uniformity.
- The total dose of the applied fertilizers is divided into several smaller portions, allowing better retention of the fertilizers in the soil and greater availability.
- Losses due to volatilization are avoided, as with volatile fertilizers such as urea and ammonium.
- Nutrigation™ permits the application of nutrients according to crop requirements; there is also a possibility of varying the ratio between nutrients during different growing stages (germination and establishment, tillering and canopy establishment, grand growth, maturity and ripening).

Savings in fertilizer and labor

- Due to the application of nutrients with irrigation water, various forms of losses are avoided. Consequently, the amount of fertilizer used to achieve the desired production level is reduced.
- Application of fertilizers via a drip irrigation system costs less compared with application by agro-machinery.

Operational advantages

- Since Nutrigation™ does not require traffic in the field, damage to plants and soil compaction are avoided.
- Nutrigation™ can maintain appropriate nutrient content in soils with low nutrient-holding capacity, allowing cultivation in types of soil otherwise not cultivable.
- The contamination of groundwater by elements of fertilizer occurs in many places where flood irrigation is used. Nutrigation™ via drip irrigation applies the amount of fertilizer and water in more frequent, smaller portions to prevent runoff or deep percolation.
- There is the possibility of applying other chemicals through the system, such as soil disinfectants and systemic products against crop diseases and pests.
- Health hazards are avoided since workers do not come in contact with the injected fertilizers and chemicals.

DRIP IRRIGATION SYSTEM OVERVIEW

Limitations

- Only water-soluble fertilizers are allowed to be used in drip irrigation.
- Some fertilizers, although water soluble, may not be compatible with the method of Nutrigation™, such as fertilizer that raises the pH of the irrigation water so high that precipitation occurs in the system.
- Certain fertilizers are corrosive to metal parts of the equipment; therefore the parts of the system that come in contact with such fertilizers must be resistant to corrosion.

Equipment for fertilizer injection into the drip irrigation system
A dosing unit serves Nutrigation™ and system maintenance:

The design of a chemical injection system involves the selection of injector type and capacity. If the injection system is to be used for Nutrigation™, the injection unit is sized for this use since injection rates for nutrients are usually much higher than injection rates for chemicals such as liquid chlorine or acid.

Any components coming in contact with nutrients, chlorine, or acid should be resistant to corrosion. Some countries require specific types of injectors for agrochemicals. Always follow local laws and chemical labeling requirements.

Dosing unit

A dosing unit is used not only for Nutrigation™, but also for chemigation.

Chemigation
Chemigation refers to injection of chemicals to prevent or reduce dripper clogging (addition of chlorine, hydrogen-peroxide, acid or others), and the injection of chemicals for crop and soil concerns (herbicides, pesticides and others).
Because the water passages in drippers are relatively small, they can become clogged; therefore, along with filtration, the capability to inject chemicals to control dripper clogging is an important feature.

The design of a chemical injection system involves the selection of injector type and capacity. If the injection system is to be used for Nutrigation™, the injection unit is sized for this use since injection rates for nutrients are usually much higher than injection rates for chemicals such as liquid chlorine or acid.

Any components coming in contact with nutrients, chlorine, or acid should be resistant to corrosion. Some countries require specific types of injectors for agrochemicals. Always follow local laws and chemical labeling requirements.

Nutrients and chemicals may be injected into pressurized drip systems via a variety of methods:
Netafim™ offers a comprehensive array of dosing systems to ensure precise nutrient delivery for any crop, plot size and application, including Fertilizer tank, Netafim™ Venturi Injectors, Hydraulic piston motor injector, FertiKit3G™ and more (for further information see http://www.netafim.com/crop/sugarcane).

Dripperlines (laterals)

Dripperlines are at the heart of a drip irrigation system. They consist of a pipe in which built-in drippers are mounted at uniform intervals. Netafim™ offers a wide variety of dripperlines with various pipe diameters, wall thicknesses, dripper spacing, flow rates and other specific characteristics, to cater for any irrigation requirements and field conditions.

Drippers

The drippers are incorporated at uniform intervals along the dripperline, to deliver water and nutrients directly to the plant root zone.

DRIP IRRIGATION SYSTEM OVERVIEW

A typical drip irrigation system includes thousands of drippers. Each dripper should be durable, resistant to clogging, and emit the same amount of water.

The flow rate and spacing of the drippers is important in determining the wetting pattern and for the prevention of runoff or deep percolation.

A properly operated and maintained drip irrigation system provides water and nutrients to the crop root zone without runoff or deep percolation.

Two types of integral drippers are available:

Non pressure compensated drippers

Non-PC drippers supply a flow rate that is based on the working pressure.

- The dripper flow rate, pipe diameter and dripper spacing determine the pressure head losses in water flow within the dripperline.
- Differences in topographic heights also affect the system.

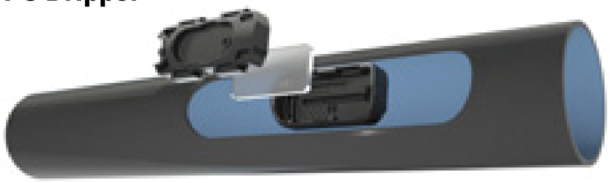
These two factors produce small differences in the dripper flow rates within the same dripperline.

Non-PC Dripper

Pressure-compensated (PC) drippers

As long as the working pressure remains within the allowable pressure range, PC drippers provide uniform irrigation by maintaining a constant flow rate regardless of the working pressure.

PC Dripper



The diaphragm is activated by the continual differential pressure created by the dripper's labyrinth, thus maintaining a constant dripper flow in a wide pressure range.

Thanks to the free-floating diaphragm, the dripper's action is precise, immediate, sensitive, continually self-adjusting and constantly self-flushing. Particles that cause clogging will either be flushed out through the wide water passages or increase the pressure differential. This causes the diaphragm to momentarily increase the cross-section volume for outgoing water, and thus flush the dirt out of the system.
The diaphragm movement maintains constant differential pressure within the water passage, resulting in a uniform flow rate at a wide pressure range.

Additionally, Netafim™ PC drippers have the added benefit of the exclusive constant self-flushing feature, which aids in the prevention of clogging.

PC drippers for particular applications:

Anti-siphon (AS) drippers

The anti-siphon (AS) mechanism prevents the suction of dirt into the dripperline, providing critical protection against dripper clogging. Ideal for subsurface drip irrigation (SDI).
Irrigation systems do not usually operate during rain. Rain often causes saturation of the soil or standing water around the dripperlines. Between irrigation cycles, when the system is not pressurized, it acts as a drainage system and pollution, if ingested, can lead to clogging of drippers.
To overcome this problem, the anti-siphon mechanism seals the dripper when the system is not pressurized, thus preventing soil particles from entering the system.

DRIP IRRIGATION SYSTEM OVERVIEW

Dripperline selection and layout design

The design process of a drip irrigation system starts with the selection of the appropriate dripper and dripperline. It involves consideration of spacing between dripperlines in the field, pacing between drippers along the dripperline, pipe diameter and wall thickness, and dripper flow rates.

Netafim™ offers a wide selection of dripperlines suitable for various irrigation needs

Thin-walled dripperlines

- Suitable for 1-3 growing seasons when laid above ground.
- Suitable for up to 8 growing seasons in SDI, resulting in substantial reduction of the drip irrigation system cost.
- Can be deployed at the beginning and rolled-up at the end of each growing season.

Medium-walled dripperlines

- Suitable for 4-9 growing seasons when laid above ground.
- Suitable for up to 10 growing seasons in SDI, resulting in substantial reduction of the drip irrigation system cost.

Thick-walled dripperlines

- Suitable for 10 or more growing seasons when installed above ground.
- Designed for a working life of many years in on-surface and subsurface applications.
- Not customary for use with SDI due to high initial establishment cost.

Surface Drip Irrigation (DI) or Subsurface Drip Irrigation (SDI)

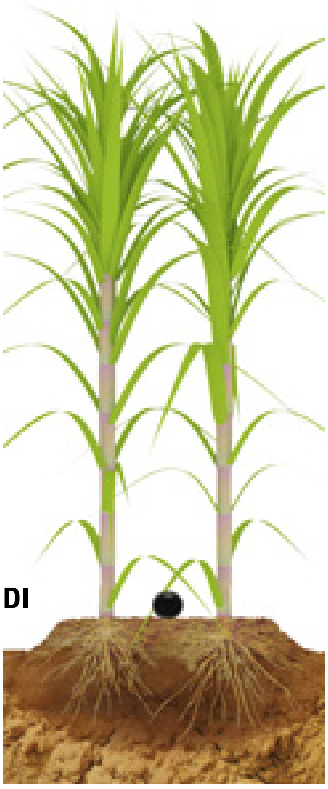
To select the appropriate type of drip irrigation system, consider the folowing factors:

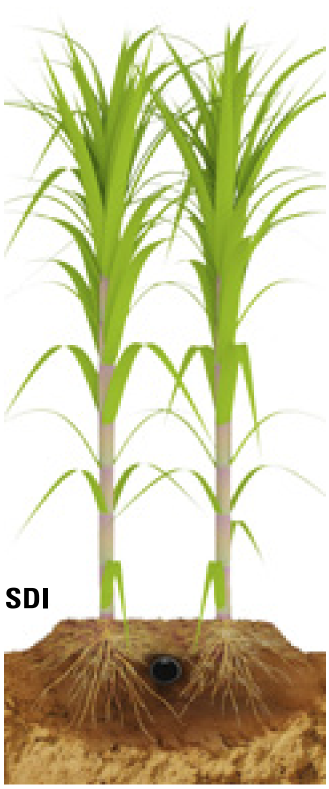
Surface Drip Irrigation (DI)

- Smallholders
- High rainfall areas
- Sandy conditions
- Easy and cost effective means to familiarize new growers with the system
- Not sensitive to root intrusion into the drippers
- Less sensitive to rodent damage
- Suitable for saline soil
- Dripperline visibility eases regular maintenance
- Excellent water distribution uniformity and efficiency

Subsurface Drip Irrigation (SDI)

- Large-scale growers and projects
- Areas with high labor costs
- Farmers with good management capabilities
- Long life expectancy
- Allows for thinner dripperline wall
- Dripperline insertion allows longer laterals
- Does not require annual retrieval of dripperlines
- Irrigation can be resumed immediately at the beginning of each growing season
- Unsurpassed water distribution uniformity and efficiency





DRIP IRRIGATION SYSTEM OVERVIEW

Advantages of growing sugarcane with SDI:

- The prime consideration for choosing SDI is the growing practice. SDI benefits from best practice farm management.
- Agronomically, SDI's prime benefit lies in the delivery of substances with low movability in the soil (pesticides, growth regulators etc.).
- SDI enables convenient, effective and extremely precise supply of water and nutrients to the crop's root zone with extreme accuracy and efficiency, reducing to a minimum the need for workers or agro-machinery to enter the field, thus avoiding damage to the crop or soil compaction, even in the crop's grand growth stage when field accessibility is restricted.
- In cases where cane burning is a necessary step in cultivation, it can be done without damaging the drip irrigation equipment.
- SDI allows irrigation immediately after harvest, without the need to wait for the agro-machinery to finish its work in the field.

Late dripperline insertion

Another method of SDI dripperline insertion is an integration of DI and SDI practices.

The dripperlines are deployed on the soil surface at the planting stage and are used for irrigating the crop during the entire germination stage (approximately two months).

At the end of the germination stage the dripperlines are inserted below the soil surface.

Advantages

- Better germination.
- Lack of dependence of dripperline insertion activities on planting (e.g., when planting is delayed).
- At the germination stage the dripperlines are visible, enabling visual monitoring of the proper operation of the system. At this stage the personnel has the opportunity to become familiar with the system's routine operation, enabling late dripperline insertion with confidence.

Late dripperline insertion is slightly more time consuming.

Controller

The best way to make full use of the advantages of a drip irrigation system is by controlling it with an irrigation controller.

Netafim™ offers an extensive range of controllers for precise monitoring and management of water and nutrient supply to the field, making full use of the exceptionally high efficiency and uniformity of the drip irrigation method.

Advantages of controlling a drip irrigation system using an irrigation controller

- Lower water, nutrient, chemicals and energy usage
- Lower labor requirements
- Real-time corrective actions
- Greater crop sustainability
- Increased productivity
- Enhanced yields

Netafim's NMC irrigation controllers are modern irrigation control systems with advanced features for handling irrigation main lines, pumps, filters, fertigation systems and other accessories related to the full comprehensive solution for farm management. The NMC line of controllers offers a range of optimal solutions for open field, greenhouse and nursery applications.

DRIP IRRIGATION SYSTEM OVERVIEW

The irrigation controller controls a multitude of irrigation system functions

- **Irrigation valves** - Irrigation control based on time and quantity.
- **Irrigation pumps** - Optimized pump control according to flow and pressure.
- **Filter flushing** based on time or pressure differential between the filter inlet and outlet.
- **Pressure sustaining valves** - Adjustment of the main line pressure when filter flushing is in process.
- **Fertilizer pumps** - Control of fertilizer injection according to the type of fertilizer pump and its flow rate.
- **Fertilizer tank selector** optimizes fertilizer usage when various crop varieties require different recipes.
- **Fertilizer agitation** - Control of agitators in the fertilizer tanks to maintain a homogeneous solution.
- **Alarm device** - Generation of an alarm in the case of a malfunction or any unusual event. Alarm can pop up on the computer screen, be e-mailed or sent as an SMS or push notification to smartphones.

The irrigation controller communicates with a variety of monitoring devices

- **Water meters** monitor the irrigation volume and flow rate and make sure that water in the system is flowing as planned, indicating the absence of leakages or clogging issues.
- **Fertilizer meters** monitor the fertilizer flow rate and amount.
- **EC and pH sensors** for advanced and accurate fertilizer control.
- **Weather station** for irrigation control based on evapotranspiration and for frost mitigation.
- **Pressure sensors** for filter flushing and irrigation control.
- **Tensiometer sensors** measure water tension in the soil for the assessment of the field capacity.
- **Soil moisture sensors** measure the volumetric water content in the soil for correct timing and precise volume of irrigation.
- **General purpose sensor** - Netafim's NMC controllers can monitor any type of 0-5 VDC or 4-20 mAmp sensor according to client needs.

Netafim™ NMC multi-mainline irrigation controller - NMC XL

- Multi-mainline irrigation controller
- Optimal solution for open field application
- Controls up to 25 central Nutrigation™ stations
- Controls up to 128 irrigation lines including flow measurement, filter flushing and local Nutrigation™

Netafim™ NMC Remote Terminal Units (RTU)

RadioNet

- Continuous wireless monitoring and optimal control at distance
- Easy-to-use modular system ensuring reliable and flexible control over remote terminal units to increase productivity and address constantly changing needs
- Multi-interface enables connection to a wide range of controllers
- Up to 254 remote units including S&F (store and forward)

SingleNet

- Up to 10 km cable length
- Reduced installation and cable cost
- Multi-interface enables connection to a wide range of controllers
- Up to 128 remote units

DRIP IRRIGATION SYSTEM OVERVIEW

Sensors

In order to make full use of the advantages of a drip irrigation system, it is important to regularly monitor the actual condition of the soil, the irrigation water, the weather and the crop. To easily collect useful data for the management of the irrigation system, Netafim™ offers a comprehensive range of high-quality sensors, either standalone or connectable to a Netafim™ CMT controller.

Operational sensors	
Water meter	A standard single jet meter that provides actual and accurate reading of water flow.
Fertilizer meter	Measures the amount of fertilizer flowing through the pipe by counting the pulses received from the reed switch.
Pressure sensor	Provides actual reading of water/fertilizer pressure in the pipe.
Soil moisture sensors	
Tensiometer	Measures water tension in the soil.
ECH_2O	One sensor that monitors volumetric soil moisture, temperature and electrical conductivity.
Environmental sensors	
PT100	Temperature sensor. Can measure air, water or soil temperature.
Weather station	Modular weather station that supports various types of sensors for wind speed and direction, air temperature and humidity, rain quantity, solar radiation, etc.

Agro-machinery

Sugarcane, being a perennial crop, enjoys the significant advantages offered by subsurface drip irrigation (SDI). The advantages of SDI are more evident in large-scale plots.

Operational costs are reduced due to the fact that the dripperlines are concealed in the soil for many years and damage to the system due to repetitive dripperline deployment and retrieval is avoided.

SDI allows the avoidance of damage to dripperlines in cases where the practice includes cane burning.

SDI has other advantages such as the possibility to use less costly thin-wall dripperlines that are protected when concealed in the soil and can thus serve for many years.

Growing sugarcane with SDI has also one disadvantage - the need for good management capability.

All these factors and reasons led Netafim™ to develop a series of mechanical tools for dripperline insertion and many options including covering tools, multiple insertion machines, shallow insertion machines with roller, dripperline releasers and more. These tools are especially optimized for sugarcane cultivation and the planting and growing practice.

A lot of thought has been invested in these tools in order to reduce damage to the drippers as much as possible.

DRIP IRRIGATION SYSTEM OVERVIEW

Subsurface insertion machinery

Subsurface insertion machines enable any grower to install dripperlines in a cost effective and efficient manner.

Subsurface insertion machines can operate in three modes:

- **Dripperline insertion only -** Performed when planting (manual or mechanical) is carried out later on. Insertion is usually GPS-aided.
- **Dripperline insertion and furrowing** - Suitable for manual planting.
- **Dripperline insertion and planting** - The insertion kit is installed on the planting machine.

The features incorporated in this tool ensure that the dripperline insertion procedure is done accurately.

The use of wear-resistant materials guarantees the integrity of the inserted dripperline.

A special plastic guide located on the insertion shank eliminates problems associated with twisted or kinked dripperlines.

Dripperline insertion in heavy soil

Dripperline insertion in sandy soil

Covering machinery

Netafim™ offers a covering machine for sugarcane. Due to the unique traits of SDI, a dedicated covering machine had to be developed.

The covering machine is equipped with a roller that compacts the soil after covering. This feature ensures adequate dispersal of water in the soil, to allow effective germination.

A pair of adjustable depth control wheels on both sides of the roller ensures an even covering layer, so that the dripperlines lay at a uniform depth.

KEY FACTORS FOR PROJECT SUCCESS

NETAFIM™ GROW MORE WITH LESS

KEY FACTORS FOR PROJECT SUCCESS

The climate, topography, soil characteristics and available water quality have significant influence on the selection of a site for sugarcane cultivation.

With drip irrigation the influence of these factors is greatly reduced, allowing greater flexibility in the selection of a site for sugarcane cultivation while maintaining the greater yield of higher-quality crops typical of drip irrigated agriculture.

Climatic considerations

Sugargane yield potential with drip irrigation is definitely the highest compared to any other irrigation method. However substantial yield variations due to local climatic conditions should be considered.

EXAMPLE

In arid areas - high radiation:

	Average yield (T/ha)
With other irrigation methods	120
With drip irrigation	150 - 170

In rainy areas - low radiation:

	Average yield (T/ha)
With rain only	70
With drip irrigation	130 - 140

The sugarcane productivity and juice quality are profoundly influenced by weather conditions prevailing during the various crop-growth subperiods.

Sugarcane is grown between 35°N and 35°S, from sea level to 1,000 m altitude or slightly higher. It is essentially considered a tropical plant. Temperature, light and moisture are the principal climatic factors that control cane growth. The plant thrives best in tropical hot sunny areas. The best climatic conditions for sugarcane growing are found at latitudes between 15° and 20° north and south.

"Ideal" climate for growing sugarcane

The "ideal" climate for production of maximum sugar from sugarcane is characterized as:

1. A long, warm growing season with a high incidence of solar radiation and adequate moisture (rainfall/irrigation). The plant uses from 148 to 300 g of water during a growing season to produce 1.0 g of dry substance.
2. A fairly dry, sunny and cool, but frost-free ripening and harvesting. Moisture percentage drops steadily throughout the life of the sugarcane plant, from 83% in very young cane to 71% in mature cane, while sucrose increases from less than 10% to more than 45% of the dry weight.
3. Absence of adverse weather conditions such as typhoons and hurricanes.

Rainfall-based irrigation has the lowest water application efficiency (up to 50%) of any irrigation method since it is impossible to control the timing, the frequency and the quantity of rain events. Thus rainfed plots are prone to significant water loss through evaporation, runoff and deep percolation.

Drip irrigation has the highest water application efficiency (95%) of any irrigation method.
Water loss through evaporation, runoff and deep percolation are virtually eliminated.

KEY FACTORS FOR PROJECT SUCCESS

Optimal climate for growing sugarcane

Crop-growth stage	Germination and establishment		Tillering and canopy establishment		Grand growth					Maturity; ripening		
DAP*	30	60	90	120	150	180	210	240	270	300	330	360
Month	1	2	3	4	5	6	7	8	9	10	11	12
Temperature °C (°F)	32-38 (90-100)				22-30 (72-86)					12-14 (54-57)		
Wind km/h (mi/h)					<60 (<37)							
Radiation mJ/m^2/day			18-36									
Rain mm/month	<100									<20		

*DAP = Days after planting

Temperature

- Optimum temperature for germination (sprouting) of stem cuttings is around 32 to 38°C.
- Optimum growth is achieved with a mean daily temperature around 22 to 30°C.
- Minimum temperature for active growth is approximately 20°C.
- Temperatures above 38°C reduce the rate of photosynthesis and increase respiration.
- For ripening, relatively low temperatures in the range of 12 to 14°C are advantageous, since this has a notable influence on the deceleration of vegetative growth and the accumulation of sucrose in the cane.

NOTE
Sugarcane grows well in areas receiving solar energy from 18 to 36 mJ/m^2 per day.

Adverse conditions

- At extremely high temperatures reversion of sucrose into fructose and glucose may occur in addition to enhancement of photorespiration, leading to less accumulation of sugars.
- Severe cold weather inhibits bud sprouting in ratoon crops and arrests cane growth.
- At temperatures of -1 to -2°C, the cane leaves and meristematic tissues are killed.
- About 7 to 9 hours of daily bright sunshine is highly useful for both active growth and ripening.

NOTE
Rough estimates show that 80% of water loss is associated with solar energy, 14% with wind and 6% with temperature and humidity.

Humidity

- High humidity favors rapid cane elongation during the grand growth period.
- A moderate humidity of 45 - 65% coupled with limited water supply is favorable during the ripening phase.

Wind

- Winds enhance moisture loss from the plants and thus aggravate the negative effects of moisture stress.
- High wind velocities exceeding 60km/h are harmful to mature canes, since they cause lodging and cane breakage.

KEY FACTORS FOR PROJECT SUCCESS

Topographical site considerations

Most irrigation methods are sensitive to the topography and cannot function where the slope of the terrain is greater than a few degrees (1-2°).

Drip irrigation adapts to any field size, shape, and topography, irrigating 100% of the field with high uniformity, maximizing production and minimizing waste.

Using pressure-compensating (PC) drippers, hills and slopes are irrigated with high uniformity.

Drip irrigated topographically undulated field

Optimal soil for drip irrigation

Drip irrigation is capable of handling any type of soil. However a well drained, deep, loamy soil having adequate aeration (10 to 12%) with a groundwater table below 1.5 to 2.0 m from the soil surface, a bulk density of 1.4 g/cm^3 and an available water holding capacity of 15% (15 cm of water per meter depth of soil) or more is considered optimal.

- Chemical constraints in the soils, such as acidity and low fertility, can be relatively easy to correct or control by means of the precise nutrient and lime application.
- Although marginal physical soil properties are more difficult to ameliorate, and are considered a limiting factor in the crop growth, drip irrigation is the preferable method to handle them, thanks to precise control of irrigation quantification, frequency and scheduling.

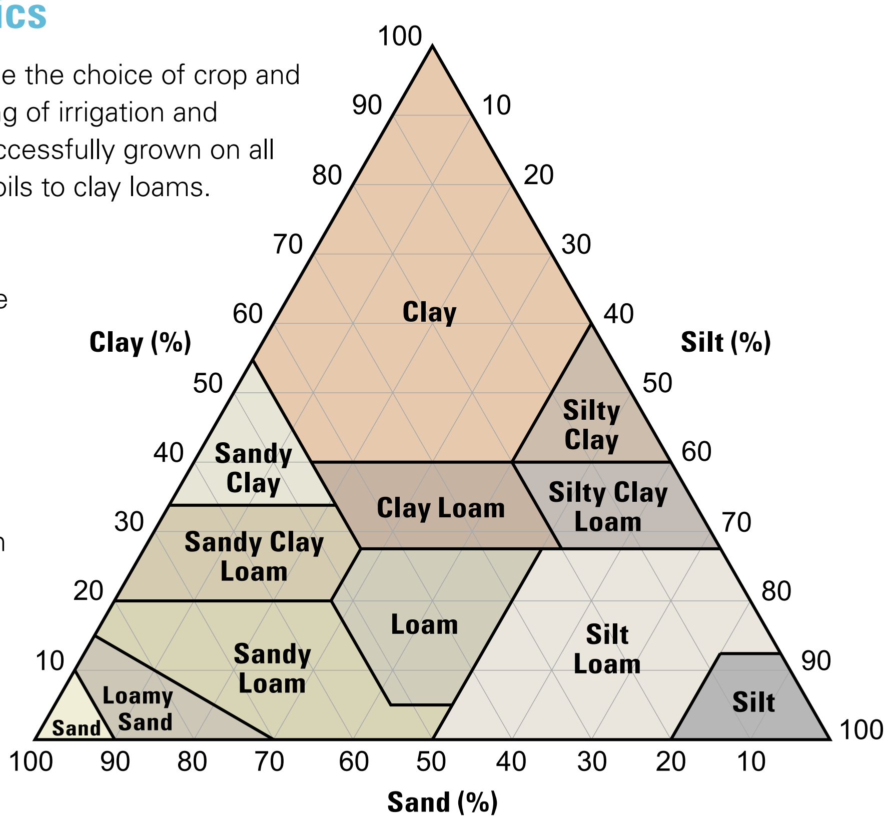
Physical soil characteristics

Soil physical characteristics influence the choice of crop and variety to be grown, and the planning of irrigation and Nutrigation™. Sugarcane can be successfully grown on all types of soils ranging from sandy soils to clay loams.

Physical soil composition

In general, soil is composed of three components: sand, silt and clay. The relative amounts of these components affect the soil's texture, influencing its water retention rate.

In most soil types the particles form larger units, known as aggregates. Aggregates stick together and form clods. Between the particles, aggregates and clods there are pores.



KEY FACTORS FOR PROJECT SUCCESS

Soil texture

The distribution of pores in the soil is important. Pores are characterized by two sizes: small and large. Small pores are known as "capillary pores." In sandy soil the porosity is permanent and stabilized. In heavy soil the porosity changes depending on changes in the soil's moisture.

Water retention is affected by the soil texture and type. For example, 15% moisture volume in a light soil will be adequate for crops to flourish, whereas the same percentage in a medium soil would be borderline and in a heavy soil would not be sufficient for plant survival.

The water is trapped in the pores and accumulates as a thin liquid layer around the soil particles. When the soil dries out as a result of percolation, evaporation and root uptake, the water is first extracted from the large pores, while still clinging to the small ones. When the plant needs water, it draws it from the pores, starting with the larger ones first.
The mechanism of water retention around soil particles is based on the retention on the surface area of these particles. Sand, silt and clay particles build up, forming aggregates, known as the soil structure. Well-structured soils have more pores and retain more water than compact soils.

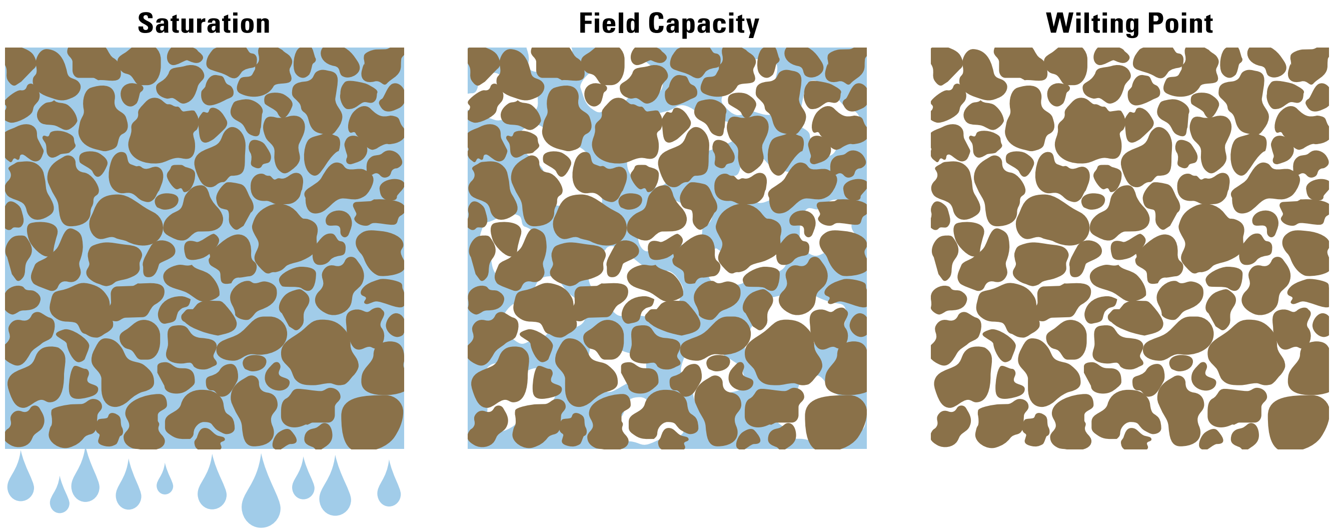
Silty soils have high water retention rates (they consist of very small particles and display a large surface area). Light soils have low retention rates (they consist of larger particles and display a smaller surface area).

Soil texture affects irrigation scheduling in two important ways:

- It determines how quickly the soil absorbs water, and it should be known prior to designing a drip irrigation system since it influences dripper flow rate and spacing.
- It determines how much water the root zone water reservoir holds, and how much of that water is available to the plant.

Soil water content

The relationship between water/soil/plant is important to understand. The following three states have an enormous impact on the crop.



Saturation
Saturation occurs when all pores in the soil are filled with water. Much of the water in a saturated field will be lost to gravity and cannot be used for plant growth.

Field capacity
Field capacity is reached when the field receives the maximum amount of water it can hold. As percolation proceeds, the soil reaches the point where it does not lose any more water. This is the optimal condition

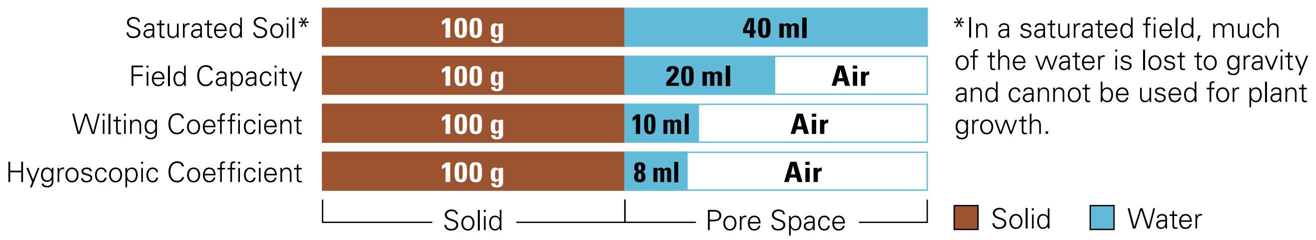
for crop development where the water is held at a force that is easily overcome by the uptake power of the roots, while at the same time the soil is sufficiently ventilated to enable the roots to breathe.

Wilting point

The state of the water in the soil that defines the point at which the plant no longer has the ability to absorb the water from the soil. Beyond the wilting point, the plant cannot survive and crop wilting is irreversible.

Water availability

Water availability is the difference between field capacity and the wilting point.



Chemical soil characteristics

Soil salinity

As cultivation becomes increasingly intensive and ineffective irrigation methods are used, many areas become affected by saline soil due to shallow, saline groundwater conditions.

A soil-salt balance must be maintained that allows for a productive cropping system. It has been experimentally concluded that sustainable sugarcane agriculture may not be possible in salt affected soils.

The salinity/drainage problem must be addressed through an improved irrigation practice.

Drip irrigation can apply water both precisely and uniformly compared with furrow, CP and sprinkler irrigation, resulting in the potential to control soil salinity.

The effect of drip irrigation on soil salinity has been evaluated based on both experimental and model results. Soil salinity data clearly showed localized leaching around the dripperlines, keeping salinity away from the root zone.

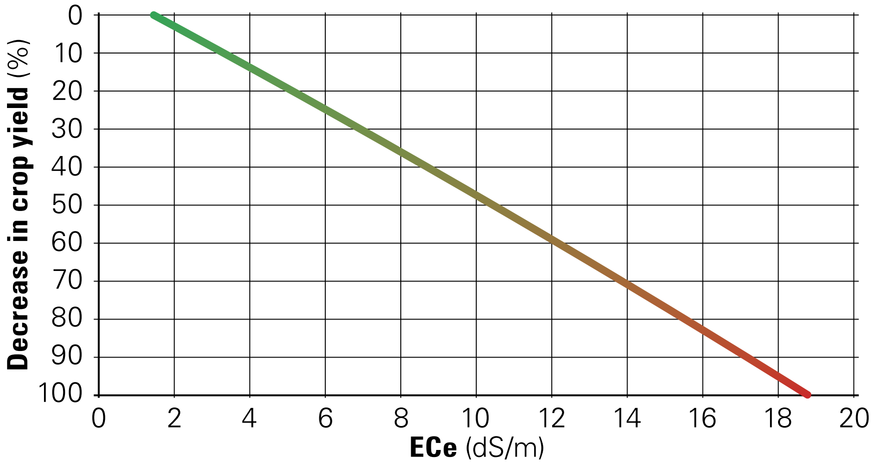
The higher the concentration of salts in the soil solution, the greater the electrical current that can be passed through it. Therefore, the electrical conductivity (EC) of the saturation extract is used as an indicator of soil salinity.

Rates of soil classification in terms of salinity and the levels considered critical to assess tolerance of cultures to excess salts are based on the electrical conductivity of the saturation extract (ECe) at 25°C.

In the past, the unit used to measure EC was mmhos/cm (milimohs per centimeter), but today dS/m (deciSiemens per meter) is the unit used.

1dS/m = 1mmhos/c.

The decrease in crop yield varies with the level of soil salinity



High soil salinity is typical of low rainfall level.

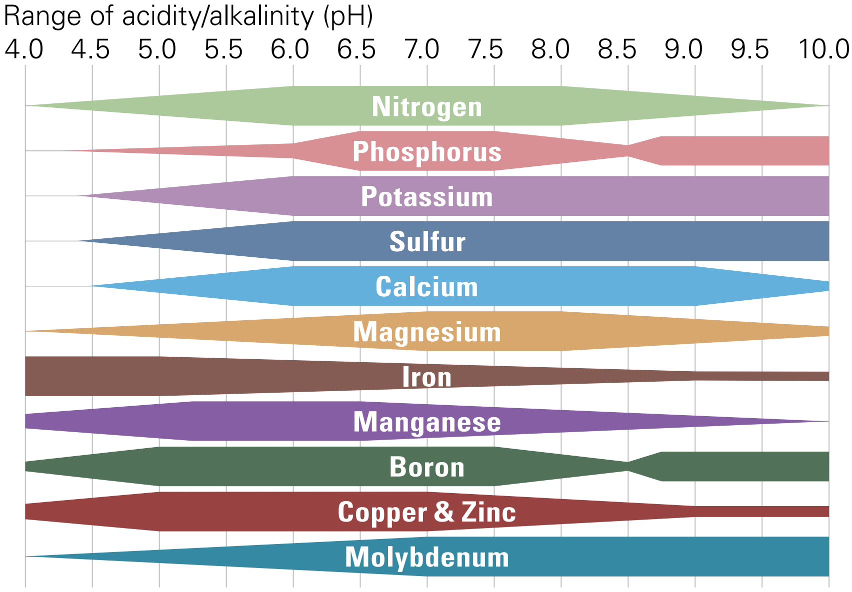
Soil pH

The soil pH is a measure of the acidity or basicity (alkalinity) in soils. pH is defined as the negative logarithm (base 10) of the activity of hydrogen ions (H^+ or, more precisely, H_3O+aq) in a solution.

In water, it normally ranges from 1 to 14, with 7 being neutral. A pH below 7 is acidic and above 7 is basic.

Soil pH is considered a master variable in soils as it controls many chemical processes that take place. It specifically affects plant nutrient availability by controlling the chemical forms of the nutrient.

The influence of soil pH on nutrient availability



Soil pH varies according to annual rainfall in the area

- Rainy areas (>1500 mm/year) - mostly acidic.
- Arid areas (<700 mm/year) - mostly basic.

Optimal soil pH for sugarcane cultivation

The optimal pH range for sugarcane cultivation is between 5.5 and 7.5, with 6.0 being ideal. It is very important to monitor soil pH and to maintain it at healthy levels.

If soil pH is lower than the required value (acidic soil):

Soil acidity can be corrected by liming the soil, or adding basic (alkaline) substances to neutralize the acid present. The most commonly used liming material is agricultural limestone, the most economical and relatively easy-to-manage source.

The limestone is not very water-soluble and cannot be implemented via the drip irrigation system. Lime should be scattered in the field and mixed in the soil upper layer using a disk plough prior to planting and dripperline insertion.

As lime dissolves in the soil, calcium (Ca) moves to the perimeter of the soil particles, replacing the acidity. The acidity reacts with the carbonate (CO_3) to form carbon dioxide (CO_2) and water (H_2O). The result is a soil that is less acidic (has a higher pH).

If soil pH is higher than the required value (basic soil):

Unfortunately, there's no quick solution to lowering a high pH soil. High soil pH doesn't happen overnight, and it won't go away overnight. Most of the high soil pH situations are the result of a drainage problem of the soil.

In this case, prevention is the best policy. Regular monitoring of soil pH and use of acidic fertilizers accordingly is the best way to prevent increased soil pH.
In mild cases, regular injection of phosphoric acid or sulfuric acid is a viable method to correct high soil pH. Since SDI focuses the irrigation to the root zone, the action of these acids is highly efficient. Other irrigation methods do not offer any practical way for dealing with high soil pH. However, since the effect of this method is short term and regular application is required in order to keep the soil pH at an adequate level, and given that acids are rather costly, it is advisable to consider the cost-over-time of such a procedure.

KEY FACTORS FOR PROJECT SUCCESS

Soil analysis

A soil analysis is necessary in order to prescribe an appropriate irrigation and Nutrigation™ plan, to determine the dripperline characteristics (dripper spacing and flow rate) and the proper spacing of the dripperlines in the field.

Physical properties

Compulsory:

- Texture (% clay, % sand, % silt).
- Depth.
- Water table - if up to 2 meters depth.

Recommended:

- Bulk density.
- Porosity.

Not required at this stage:

- Structure.
- Storage capacity - availability.
- Water movement.

Chemical properties

Compulsory:

- pH [Water or CaCl].
- Organic matter (%).
- Electric conductivity [extraction saturate].
- N - Nitrate.
- Phosphorus [if pH above 7- Olsen] (ppm).
- Potassium (meq/100 g soil).
- Sodium (meq/100 g soil).
- Calcium (meq/100 g soil).
- Magnesium (meq/100 g soil).
- $CaCO_3$ active (%).
- Al - Ammonium acetate [only on acid soils if pH below 5 (meq/100 g soil)].
- Sulfur (ppm).
- Boron [hot water] (ppm).
- SAR.
- ESP.
- Saturation point - (% water quantity in relation to sample weight).

Recommended:

- Iron (ppm).
- Copper (ppm).
- Manganese (ppm).
- Zinc (ppm).

Not required at this stage:

- Nitrogen total (%).
- Carbonate [extraction saturate].
- Bicarbonate [extraction saturate].
- Cation Exchange Capacity (meq/100 g soil).

*For some of the parameters, the preferred method is in square brackets [], and the recommended units in parentheses ().

Soil survey

In new projects, a soil survey is necessary in order to select the most suitable soils in the region for sugarcane growing and to create a uniform block that will facilitate operations and reduce the investment costs.

One of the key aspects for the soil survey will be the water table depth and the proposed drainage system.

The soil survey must take into consideration the following:

Number of soil samples: After selection and mapping of the area, a visit will be made to determine the number and location of samples for the soil survey. The number will be defined according to the hydraulic design of the project, at least one soil pit per shift.

Soil sampling process:

Soil sampling should be done using an excavator to open a soil profile of up to 1.5 m depth in order to identify the different soil layers of each profile. Once the soil layers are identified a sample should be taken from each 30-cm layer.

All soil pits must be documented with a digital camera. The documentation must include the following information about each pit: coordinates, altitude (m), topography (flat, hilly, mountainous), slope (%), vegetation (none, bush, forest), drainage (good, moderate, none).

KEY FACTORS FOR PROJECT SUCCESS

Crop water requirements

When planning a new drip irrigation system, the first thing to consider is the ability of the water source to supply a sufficient quantity of water for the planned project.

Required water quantity

When calculating the quantity of water required for a project, there are 2 main criteria to consider:

- The total quantity of water required for a growing period (seasonal, yearly, etc.).
- The daily quantity of water required at peak demand.

These 2 criteria, although connected, are not interdependent (i.e., fulfillment of one of them does not necessarily imply fulfillment of the other). In a well planned irrigation system, both criteria are met throughout the entire growing season.

NOTE

Both parameters must be taken into consideration at the preliminary data collection stage. If not, it might be difficult and expensive to correct the system later on.

Seasonal water quantity

Calculation of the required seasonal water quantity is based on various factors, including the water source, the crop's needs, the size of the field, water availability, water quality and the water conveyance and storage system.

EXAMPLES

- A river supplies water of adequate quality at a sufficient quantity according to the crop's needs and the size of the field, but the water conveyance system and pumps are of insufficient capacity. Adequate water supply throughout the whole growing season cannot be guaranteed.
- There is a well planned water conveyance and storage system, but the reservoir remains empty due to failure of the water source (river, well, bore) to fill it with a sufficient quantity of water at the appropriate time.
- A bore supplies a sufficient flow rate according to the crop's needs and the size of the field, but every 24 hours pumping must be interrupted to allow the aquifer to refill. It might be impossible to supply the required seasonal water quantity.

The daily peak water requirement

The maximum daily quantity of water required takes into consideration diverse variables, such as the ever-changing daily needs of the crop at each growing stage, the daily local climate, the soil characteristics and the daily irrigation hours allowed.

The combination of all these variables is expressed by 2 agronomical definitions:

- **Kc - Crop coefficient** represents the effect of the crop aspects.
- **ET - Evapotranspiration** represents the effect of the various climate conditions.

Calculating the daily peak water requirement

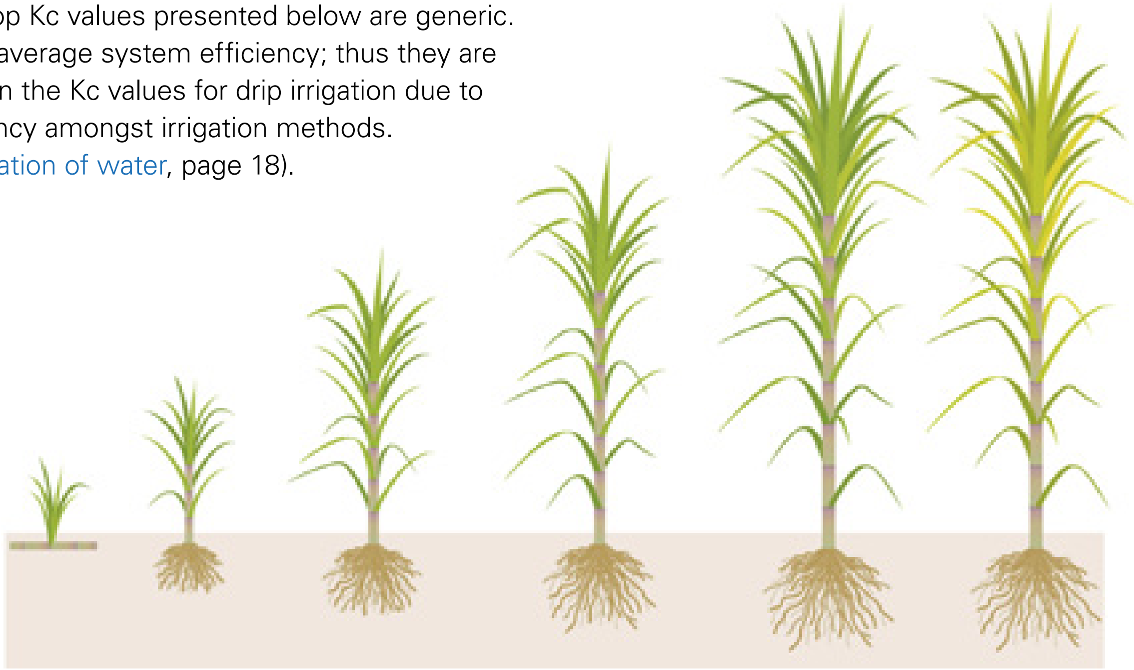
ET multiplied by Kc results in the daily water requirement (DWR).

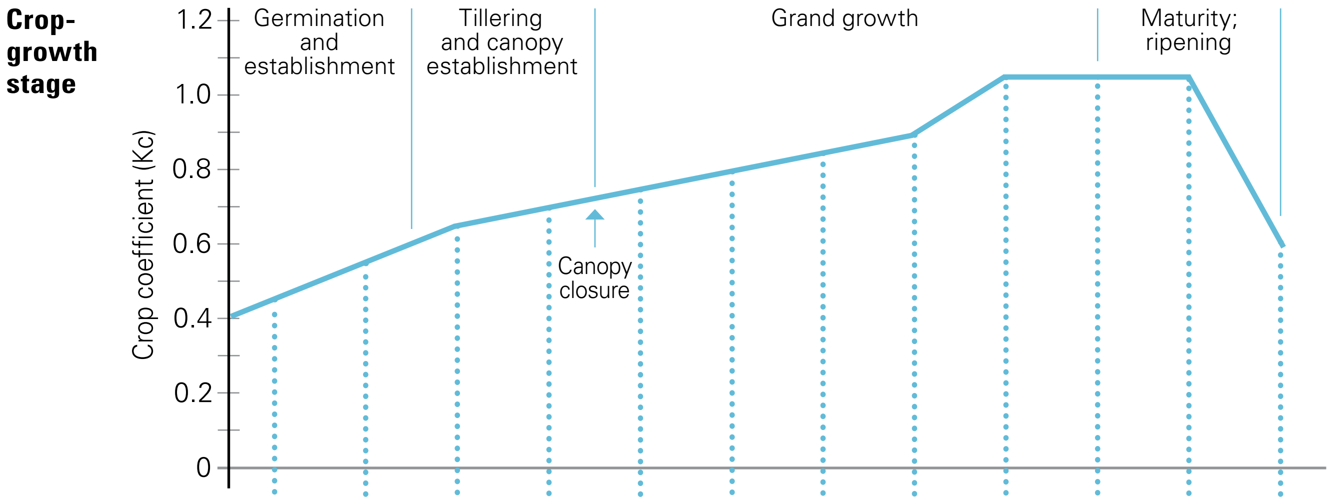
To derive the daily peak water requirement, add a safety margin according to specific local conditions, considering the daily irrigation duration (normally between 18 and 22 hours) in order to allow additional irrigation that might be required in unusual situations.

Since each parameter considered while planning an irrigation system affects the overall cost of the system, it is highly recommended to consult an agronomist and an irrigation designer in order to determine the required quantity of irrigation water as accurately as possible.

Crop coefficient (Kc) along the growing period

The sugarcane crop Kc values presented below are generic. They consider an average system efficiency; thus they are slightly higher than the Kc values for drip irrigation due to its highest efficiency amongst irrigation methods. (see Actual application of water, page 18).





DAP*	30	60	90	120	150	180	210	240	270	300	330	360
Month	1	2	3	4	5	6	7	8	9	10	11	12
Kc	0.45	0.55	0.65	0.70	0.75	0.80	0.85	0.90	1.05	1.05	1.05	0.60

*DAP = Days after planting

Calculating the irrigation rate

Rain is typically measured in millimeters or inches.

The measured datum is the depth of rain water that would accumulate on a flat, horizontal and impermeable surface during a given amount of time. One millimeter of rainfall is the equivalent of one liter of water per square meter.

This datum can be extrapolated to an area to calculate the volume of water that has fallen on the area: If 50 mm of rain fall on an area of 10,000 m^2, the volume of water will be 10,000 m^2 * 0.05m or 50 m^3.

Milimeters (mm) to cubic meters (m^3) conversion

- 1 mm of rain = 1 liter per square meter (50 mm of rain = 0.05m)
- 1,000 mm of rain = 1000 liter or 1 m^3 per square meter

EXAMPLE

Calculating the Precipitation Rate (Pr)

Data

- Dripper flow rate (l/h) Q = 1.0 l/hr
- Distance between drippers (m) E = 0.5 m
- Distance between dripperlines (m) D = 1.8 m

Calculate the precipitation rate as follows:

$$\text{Precipitation rate (Pr)} = \frac{Q}{(E \times D)} = \frac{1.0}{(0.5 \times 1.8)} = 1.11 \text{ mm/h}$$

Calculate the daily water requirement (DWR):

Data

- Pan evaporation (mm/day) ETo = 8.1 mm/day
- Crop coefficient Kc = 0.75

DWR = 8.1 * 0.75 = 6.1 mm/day

Calculate the required irrigation duration (hours/day):

$$\text{Daily irrigation time} = \frac{6.1 \text{ mm/day}}{1.11 \text{ mm/h}} = 5.5 \text{ h (5 hours 30 minutes*)}$$

*Conversion of decimal hours to minutes: $\frac{\text{decimal hours}}{100} * 60$ $\quad \frac{0.5}{100} * 60 = 0.3 = 30 \text{ min}$

Maximum daily irrigation time = 22 hours

The maximum planned daily irrigation time should not be higher than 22 hours, in order to leave spare time for unexpected system maintenance events and required changes in the irrigation plan.

$$\text{Number of shifts per day} = \frac{22 \text{ h/day}}{5.5 \text{ h/day}} = 4 \text{ irrigation shifts/day}$$

If irrigation is timed to be carried out only once in a few days, multiply the DWR by the number of days between irrigations and calculate the daily irrigation time accordingly.

KEY FACTORS FOR PROJECT SUCCESS

Water quality

Water quality refers to the variety and concentration of the dissolved and suspended components in the water that have an influence on its quality (such as poisonous substances and salinity).

The quality of water for drip irrigation refers to the parameters affecting the irrigation system.

A pressurized irrigation system requires attention to the water quality to avoid clogging of the irrigation components in order to enable proper irrigation according to the irrigation program throughout the entire life of the system.

The water's chemical characteristics are influenced by the variety and concentration of the substances dissolved in it.

These dissolved substances include ions of dissolved salts such as chloride and sodium and nutrients (nitrogen, phosphorous, potassium and others). Calcium and magnesium influence the hardness of the water; iron and manganese are liable to be found either dissolved or as a residue, along with other dissolved organic compounds and even poisonous substances.

The biological characteristics of the water quality include a variety of living organisms such as micro-organisms, including bacteria, viruses, single celled entities, algae and zooplankton that develop in open waters along with creatures developing within the water transport system itself.

The water quality is expressed by the physical conditions and the variety and concentration of its constituents and is determined by a wide variety of parameters (measured or calculated) affecting the crop, the soil and the irrigation system. Some of them are listed in section 6, page 51.

The water quality required for drip irrigation cannot always be defined in terms of particle sizes or the concentration of any specific factor, because of the complexity of the clogging factors and the changes occurring in them as they travel through the irrigation system. Changes such as water temperature, water pressure and flow rate all influence the crystallization, unification and settling of suspended dissolved compounds.

The most suitable way of defining the required irrigation water quality is to know of all the clogging factors and determine an upper permitted threshold value for them in water arriving at the irrigation system without fear of clogging or damage to the system.

Water analysis

A water analysis is necessary in order to select the right type of dripper and the appropriate type of filtration system, to prescribe a suitable maintenance program, to select the type of dripperlines and to prescribe an appropriate Nutrigation™ plan.

Analyze the water used in the irrigation system and determine its quality:

The water quality refers to the concentration of chemical substances dissolved and suspended in the water, as well as the physical and biological properties of the water.

Water quality for agriculture is defined according to the following criteria:

- **Agronomic water quality** - the extent of its compatibility with the type of soil and with the crop.
- **Water quality for irrigation** - the extent to which it will induce clogging of the irrigation system.

The source of water may be: potable water, waste water, residual water, wells, reservoirs, canals or drainage water. Each one requires different levels of treatment before being used.

It is recomended that the irrigation water be analyzed at least once a growing season and, if needed, during the growing season, considering meteorological and environmental factors that could potentially influence the water quality. Consult Netafim's agronomic department (especially recommended for new projects).

KEY FACTORS FOR PROJECT SUCCESS

The grower has no control over the water quality, which varies with time. This means that different treatments are required at different times in order to ensure that water quality is suitable for the irrigation system.

Therefore, it is recommended that the water be analyzed occasionally in order to constantly adjust the treatment.

Other factors that affect the water quality and must be taken into account are the fertilizers and chemical products used in the same system for various treatments.

Taking water samples:

1. Before taking a water sample, flush clean a 1-liter bottle, using water from the source to be sampled.
2. Fill the bottle so that no air at all remains inside the bottle (if possible, squeeze the bottle to expel anyremaining air).
3. Close the cap firmly and store the sample in a clean place in the shade.
4. Send the sample to a local authorized laboratory as soon as possible after taking the sample.
5. Write the following data on the sample bottle:
   - Grower's name ■ Location ■ Water source ■ Date the sample was taken
6. Request an analysis of all the following parameters:
   - **EC** (electrical conductivity)
   - **pH** (level of acidity or alkalinity)
   - **Ca** (calcium - hardness of the water)
   - **Mg** (magnesium)
   - **Na** (sodium)
   - **HCO_3** (bicarbonate)
   - **CO_3** (carbonate)
   - **Alk** (alkalinity)
   - **Cl** (chloride)
   - **SO_4** (sulfate)
   - **Fe** (iron)
   - **Mn** (manganese)
   - **TSS** (total suspended solids)
   - **TDS** (total dissolved solids)
   - **Turbidity**
   - **K** (potassium)
   - **PO_4** (phosphate)
   - **$N\text{-}NH_4$** (nitrogen-ammonium)
   - **$N\text{-}NO_3$** (nitrogen-nitrate)
   - **B** (boron)
   - **Algae** and **Chlorophyll**
   - **Zooplankton**
   - **BOD** (biochemical oxygen demand*)
   - **COD** (chemical oxygen demand*)
   - **VSS** (volatile suspended solids*)

   *When waste water, mill effluents such as vinasse and/or recycled water are used.

All the above parameters are essential for correct analysis.

In some cases, additional parameters will be needed in order to complete the correct interpretation of the water quality, for example: dissolved oxygen, redox, etc.

If in doubt, consult the Netafim™ laboratory regarding water quality.

7. Taking a sample from the end of a dripperline:
   - Wait until the pressure has stabilized.
   - Open the end of the dripperline and let water flow for 2-3 minutes before taking the sample.
8. Taking a sample from the head control outlet:

To estimate the filtration efficiency, the sample should be taken downstream from the head control outlet, after the system has been working for at least one hour.

NOTE

Take the samples downstream from the pump, but as close to it as possible.

If the field to be irrigated is located more than 1 km away from the pump, take another sample of water at the head of the plot.

In new irrigation projects, water samples should be taken as close as possible to the planned suction point.

KEY FACTORS FOR PROJECT SUCCESS

Choice of varieties

Variety is the axis around which production revolves. Therefore selection of appropriate sugarcane varieties is a prerequisite for successful cultivation of sugarcane.

Sugarcane variety development institutes and companies constantly work on the development of new varieties of sugarcane with better characteristics for eventual higher profitability. The use of those varieties is subject to royalties charges.

In many countries academic institutions conduct scientific research for the development of improved sugarcane varieties, and statutory bodies issue regulations regarding the sugarcane variety market.

In some countries agreements between growers and variety development companies for the use of a specific sugarcane variety are customary.

Objectives of sugarcane breeding

When breeding a new variety, the required characteristics are:

Productivity & quality	Tolerance	Adaptability	Response	Harvest
■ Biomass	■ Diseases	■ Climate	■ Ripening	■ Period (early, mid, late)
■ Sugar	■ Pests	■ Soil	■ Irrigation	■ Period of industrial use
■ Fiber	■ Drought			■ Mechanization

The effect of harvest date on the selection of a variety

Early maturing varieties

Early maturing varieties are ready for harvest within 10-11 months. In general, early varieties are planted early in the planting season and are crushed during the earlier part of the crushing season.
When harvesting at the beginning of the season, sugar content tends to be low due to the short period between the rainy season and the harvest. Thus, the requirements for induction of early maturing varieties are relatively lower.

Mid-late maturing varieties

These varieties are generally planted during the middle of the planting season and harvested likewise. They are generally high yielding.

Late maturing varieties

The late varieties are harvested late to meet the late crushing needs of the factory. Most of the late varieties are high yielding but generally have lower sucrose recovery levels than either early or mid-late varieties.

The reaction of different varieties to irrigation

The response of a sugarcane variety to irrigation is determined by its water stress mechanism. During periods of water stress, the plant attempts to adjust. Water-deficit stress alters a variety of physiological processes in the plant, such as stomatal conductance, transpiration rate and many others. These physiological traits are associated with crop growth and yields.

How to select a variety suitable for drip irrigation

Varieties that respond well to drip irrigation are varieties with a stress mechanism that is less sensitive to water stress, and not easily activated. Therefore under good soil humidity their growth is hardly inhibited and this results in relatively higher yields.

KEY FACTORS FOR PROJECT SUCCESS

Sugarcane nursery

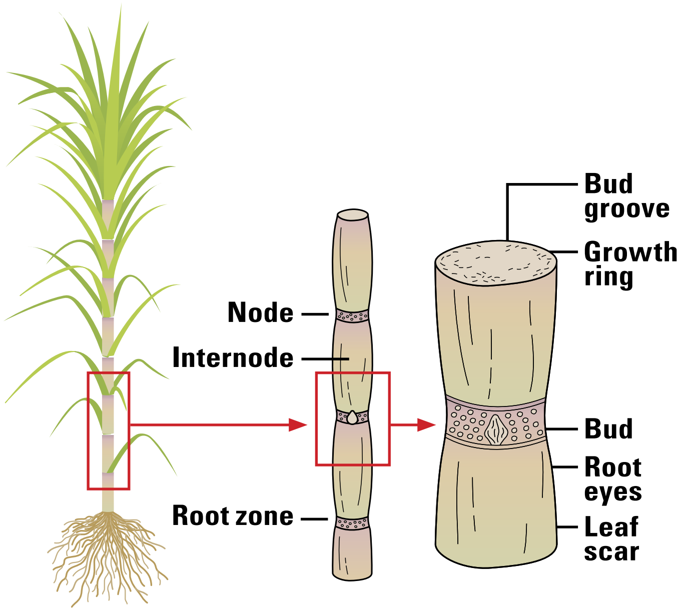
Since sugarcane is a perennial crop and once a variety has been selected it is annually cultivated and harvested for up to 10 years (9 ratoons), it is important to plant healthy, of disease-free seed cane in order to ensure yield quality and quantity throughout these years.

CAUTION
Diseases introduced into a new crop by the planting of infected seed cane may gravely undermine productivity for many years.

The establishment of a cautiously managed seed cane nursery that includes treatment of the seed cane to eliminate pathogens and pests is a common practice for producing the healthy seed cane of your choice for planting. The general guidelines for establishment and operation of a seed cane nursery are described below.

Seed cane - Concept

- The seed cane can be defined as vegetative planting material, which must be between 6 and 9 months of age.
- 6 to 10 tons-per-hectare of seed cane material are needed to plant fields.
- Setts should be cut to 60 cm long (3-4 buds per sett).
- The material used for seeds must be pure in terms of variety, vigorous in its germination and free of pests and diseases.



To ensure healthy seed production a 3-stage nursery is used

- **Basic seeds**
- **Semi-commercial seeds**
- **Commercial seeds**

Basic seed

- Planting material from tissue culture (planting and first ratoon).
- Ensures high varietal purity (100%) in the field.
- Systemic infectious diseases are controlled using hot water treatment.
- 2 phytosanitary assessments are conducted: The first at 4 months; The second before cutting the seed.

Hot water treatment of the buds

- Hot water treatment is used to eliminate the presence of certain diseases (leaf scald, rickets, red stripe, mosaic, YLS).
- Dip planting material in hot water at 51°C (124°F) for one hour.

Semi-commercial seeds

- Planted with seedlings from basic material.
- Usually 1 block of semi seedlings is used to establish 6 blocks of commercial seed.
- 2 phytosanitary assessments are conducted.

KEY FACTORS FOR PROJECT SUCCESS

Commercial seeds

- Established with material from the first ratoon plant or a semi seedbed.
- 2 phytosanitary assessments are conducted.

Timing seed setting

Plan the time of seed setting according to the planting program of the farm.

Steps for establishing a commercial seed nursery

1. Selection of variety to propagate
2. Selection and cutting of the seed
3. Fungicide and insecticide treatments
4. Soil preparation
5. Field planting
6. Fertilization
7. Monitoring of pests and diseases

Criteria for evaluating commercial seeds

Varietal purity	> 95%
Cycle	0, 1 and 2
Age of the plantation	6 to 9 months
Damage from borers	≤ 2%
Damage from rats	< 4%
Damage from diseases	≤ 3%

Soil preparation

Soil preparation is essential for the future performance of the system and should be applied throughout the entire area at the initial stage of the project. In some projects, this may not be possible at the initial stage because of climate conditions or because planting dates for some fields are a long time after project initialization. For these projects, the initial stage of land preparation should be performed only for the strips of mainline, sub-main and flushing manifold routes (4 m strip). Performe full land preparation of the entire area later, just before dripperline injection and planting.

Sugarcane can remain in the field for up to 8 to 10 years due to the practice of raising up to 9 ratoon crops with drip irrigation. Thorough land preparation that brings the soil to fine tilth is essential for proper germination of the setts, crop protection from diseases and and, eventually, contribution to multiple ratoons.

Tilth is a descriptor of soil. It combines the properties of particle size, moisture content, degree of aeration, rate of water infiltration, and drainage into abbreviated terms in order to more easily present the agricultural prospects of a piece of land.

Ideal soil tilth (ideal physical condition of the soil) enables planting at an optimum depth as well as uniform water distribution for field emergence and establishment of the crop.

Installation of dripperlines should be performed before planting the first crop. Proper land preparation is an essential prerequisite for laying dripperlines at the desired depth without incurring any damage.

A typical land preparation process includes:

- Deep cross-ripping cultivation using a subsoiler.
- Plowing to a depth of at least 25 to 30 cm.
- Cultivating the entire area using a disk cultivator in order to crush soil clods.
- Leveling the area using a leveler.
- Forming beds in the right size and direction.
- Finally, compacting the soil using a roller.

NOTE

Before inserting the dripperlines, all natural and artificial obstacles should be removed, such as: stones, rocks, metal rods, thick stalks, etc. During land preparation, ensure that the entire area is treated, leaving none of the site's borders uncultivated.

KEY FACTORS FOR PROJECT SUCCESS

GPS usage

In many locations, insertion of the dripperlines is performed with the aid of a Global Positioning System (GPS). This method is becoming increasingly popular and is highly recommended by Netafim™.

The integration of GPS technology in a sugarcane project from initiation improves planning and saves time and labor.

Advantages of GPS-aided precise in-field agro-machinery traffic:
- Minimized soil compaction.
- Avoidance of damage to the irrigation system and the dripperlines in SDI.
- Avoidance of damage to the crop.

GPS operation

GPS is a space-based global navigation satellite system. The satellites orbiting earth transmit special code sequences, which are received by the GPS receiver installed, in our case, on the tractor/agronomic machine.
The position of the tractor is calculated based on signals received from at least four satellites. The multiple signals are processed by the receiver to deduce its exact location.

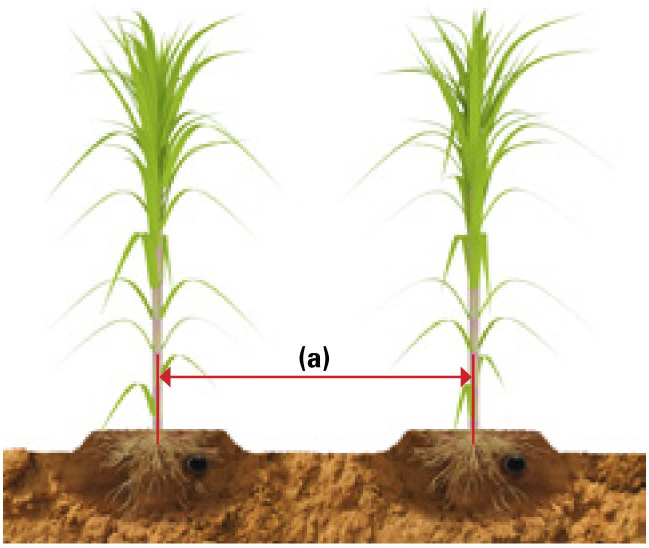
Auto Steering
Auto steering, like airplane autopilot enables higher accuracy in dripperline insertion, planting and infield agro-machinery traffic.
Auto steering systems are available for most tractors/agricultural machines.

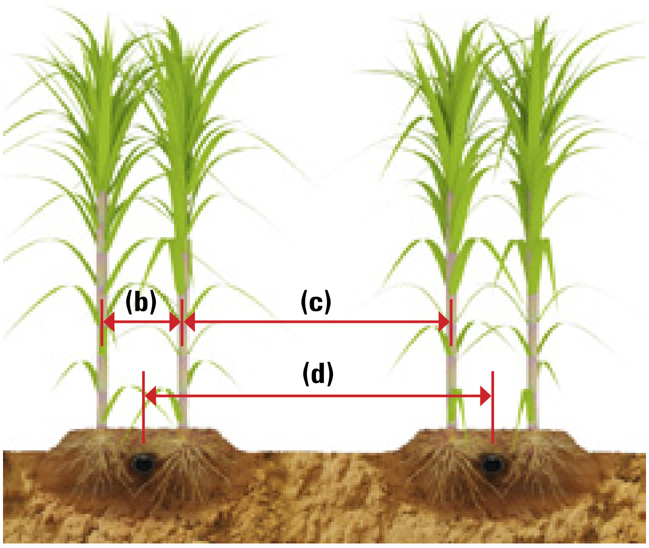
Row spacing, planting distances and traffic control

Single row or dual row planting

Single-row planting
- Emitter spacing: 0.4 m-0.6 m
- Emitter discharge: 0.6-1.3 l/h
- Optimal stalk population: 110,000 plants/ha
- Distance between adjacent rows (a): 0.9 m to 1.5 m

Dual-row planting
- Emitter spacing: 0.4 m-0.6 m
- Emitter discharge: 0.6-1.3 l/h
- Optimal stalk population: 130,000 plants/ha
- Distance between adjacent rows (b): 0.4 m to 0.6 m
- Distance between far rows (c): 1.4 m to 1.9 m
- Distance between dripperlines (d): 1.8 m to 2.2 m





KEY FACTORS FOR PROJECT SUCCESS

The advantages of dual-row planting for sugarcane

- **Controlled traffic** - dual-row planting is better suited to farm machinery, enabling reduced soil compaction and less dripperline and crop damage.
- **Increased yields** - dual-row fields generate higher yields due to heavier stalks, increased plant population, improved root development and better overall manageability.
- **Lower system cost and complexity** - the use of one dripperline irrigating two crop rows significantly reduces system cost and complexity.

Prof. Atilio Casagrande of Sao Paulo State University (UNESP) reviewed more than 155 studies on plant spacing in sugarcane, which showed that the narrower the spacing the greater the yield (a yield increase of 1% for each 3 cm of density).

When considering row spacing for mechanical cultivation and harvest:

It is very important for the drip irrigation system that all heavy machinery travel only on the designated paths and not on the stools or the dripperlines.
Row spacing should match the equipment wheel tracks to avoid soil compaction which reduces tillering and stool health, as well as reducing the water holding capacity of the soil and damaging the dripperlines.

The common spacing used for drip irrigation is 1.8 m or 1.9 m; thus it is valid either when planting in dual rows: 1.40 x 0.40 or 1.50 x 0.40, or in single rows of 1.8 m.

The machinery wheel width is 60 cm in most cases.

Dual row spacing of 1.8 or 1.9 m will provides 3 benefits:

- **Higher yields** due to the increase in plant population: 11,111 rows per hectare compared with 6,666 rows with a 1.5-m single row; the use of drip irrigation eliminates the plant competition over water and nutrients.

- **Better positioning of the dripperlines:** each dripperline is located in the center of the dual row, protected from damage. One dripperline irrigates two rows of plants (cost economization) with the same efficiency.

- **Best spacing for traffic control**, because the track goes down the furrows between the rows, avoiding the hills and the plants.

Field design and harvest

When planning drip irrigation, the field should be designed to fit the mechanical harvesting system, for minimization of in-field traffic and unnecessary soil compaction.

Training of personnel

Well-trained personnel is of utmost importance to the success of a drip irrigation project. The farm personnel must be familiar with all the relevant agronomic and operational practices and issues.

In order to ensure the best and most up-to-date practices, farm personnel training services are provided around the globe by Netafim's international team of experts.

Training includes:

- Seminars and workshops
- Regular on-site visits
- Mini-courses
- Permanent on-site technician and agronomist

The topics include:

- Soil, water and plant interaction
- Drip irrigation technology
- Agronomic issues
- Design of irrigation systems
- Hydraulics
- Maintenance

KEY FACTORS FOR PROJECT SUCCESS

On-site technical support and training

An irrigation expert is present at the project site on a full-time basis for initiation of local personnel. His role is to support and guide irrigation system operation, system maintenance and irrigation management including classroom and on-the-job training for the local team, to ensure they gain the skills and knowledge to operate the system for many years to come.

Agronomic support (post commissioning)

An expert agronomist is present at the project site on a full-time basis for a long period. His role is to support, guide and train the local team on irrigation scheduling, Nutrigation™ programs, crop protocols and all other agronomic and agricultural activities related to the best use of the drip irrigation system.

Maintenance

Maintenance is the most important means to help keep the drip irrigation system running at peak performance and to increase its life expectancy.

Drip irrigation of sugarcane is generally done by SDI. In addition the dripperlines are to remain in the soil for up to 10 years. The use of medium-wall-thickness dripperlines requires the implementation of a scrupulous maintenance procedure.

The best way to determine whether the maintenance program is effective is to constantly monitor and record the system flow rates and pressure.

Maintenance consists of two categories:

- **Preventive maintenance**, aimed at preventing clogging of the drippers, can be divided in three categories:
  - Flushing the system.
  - Chemical injection.
  - Irrigation scheduling.

- **Corrective maintenance** consists mainly of removal of obstructions already present in the drippers:
  - Organic formation - treated with hydrogen-peroxide.
  - Mineral sedimentation - treated with acids (or a combination of acid and hydrogen-peroxide).

Maintenance timetable

When operating a new system for the first time

- Flush the piping - main line, sub-mains and distribution pipes.
- Flush the dripperlines.
- Check actual flow rate and working pressure for each irrigation shift (when the system is active for at least half an hour).
- Compare the collected data to the data supplied with the system (planned). The tolerance should not be greater than ±5%.
- Record the new acquired data and keep it as a benchmark for future reference.
- If the flow rate and/or the working pressure at any point in the system differ by more than 5% from the data supplied with the system, have the installer check the system for faults.

Once a week

- Check actual flow rate and working pressure for each irrigation shift under regular operating conditions (i.e., when the system is active for at least half an hour and stabilized).
- Compare the collected data to the benchmark data.

KEY FACTORS FOR PROJECT SUCCESS

- Check for water reaching the end of all the dripperlines.
- Check the pressure differential across the filters.

Once a month

- Flush the dripperlines (might be required at a lower or higher frequency, depending on the type and quality of the water).
- If the filtration system is automatic, initiate flushing of the filter/s and check that all the components work as planned.
- If pressure-regulating valves are installed, check the pressure at the outlet of each one of them and compare it to the benchmark data.

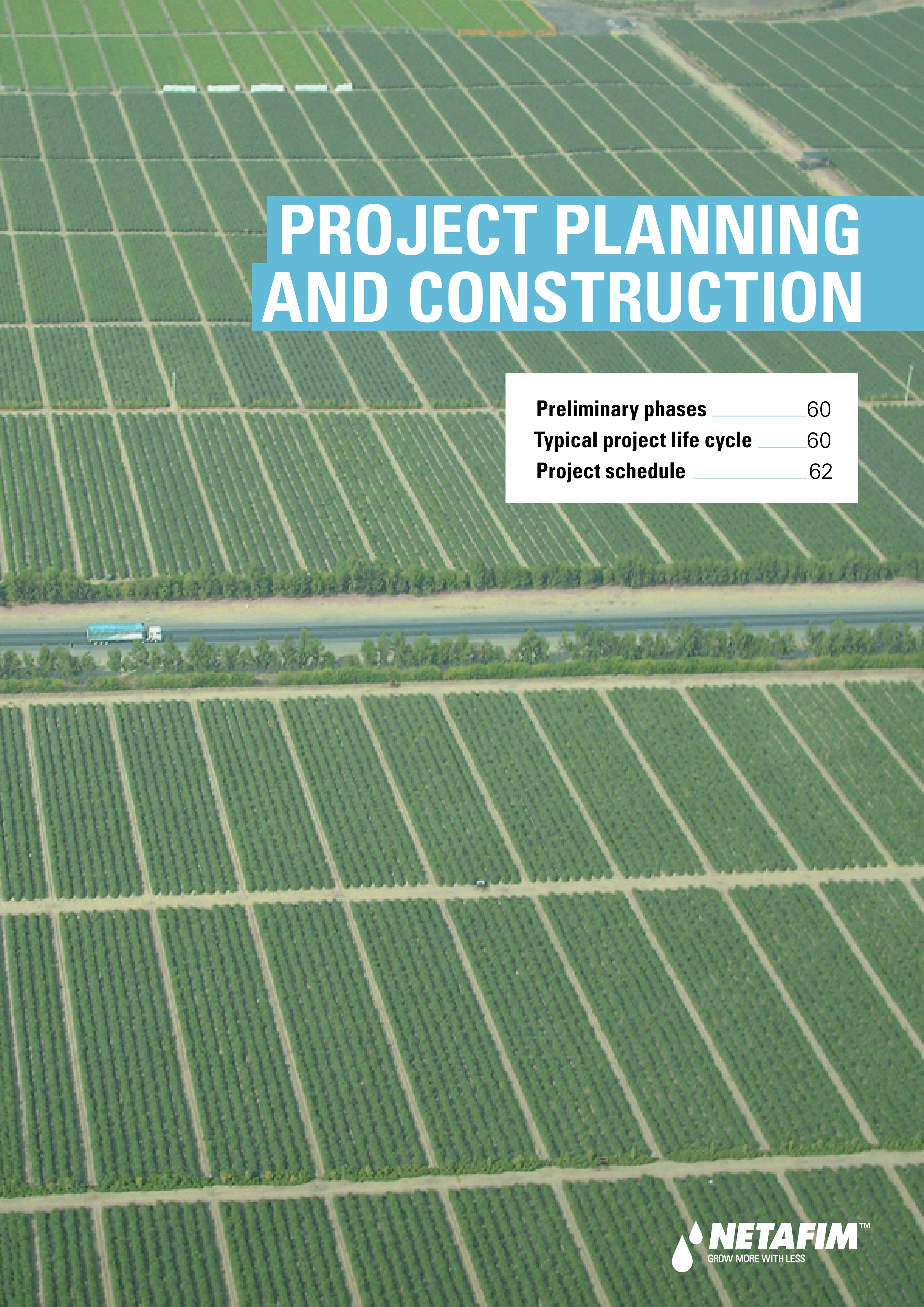
Once a growing season

In some cases this needs to be performed twice or three times in a growing season, depending on the type and quality of the water used.

- Check the level of contamination in the system (carbonates, algae and salt sedimentation).
- Check for occurrence of dripper clogging.
- Flush the piping - main line, sub-mains and distribution pipes.
- If necessary, inject hydrogen-peroxide and/or acids as required.

At the end of the growing season

- Inject chemicals for the maintenance and flushing of the main line, the sub-main lines, the distribution pipes and the dripperlines.
- Flush the dripperlines.
- Prepare the system for the inactive period between growing seasons.
- Perform winterization of the system in regions where the temperature might drop below 0°C (32°F).



PROJECT PLANNING AND CONSTRUCTION

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PROJECT PLANNING AND CONSTRUCTION

Preliminary phases

When considering a new sugarcane project it is highly recommended to implement two preliminary phases before starting the project planning:

Pre-feasibility assessment

A report, including preliminary assessment of project viability and key points to be considered when making the go/no go decision.

- **Goal:** To assist investors in determining the suitability of land for the project and the project's financial viability; raise risks and concerns at an early stage.
- **Common content:** Site visit by experts to determine the suitability of land for the project, consider potential challenges and develop a preliminary master plan.
- **Deliverables:**
  - Pre-feasibility report with initial assessment of project's fundamental aspects.
  - Business concept and budgetary estimates.

Feasibility assessment and business plan

Detailed feasibility assessment, including economic and operational aspects; conceptual design, implementation and operational plan of project.

- **Goal:** To present a detailed feasibility and proposed project outline, including a clear approach for project execution with plan, schedule and budget.
- **Common content:** Additional site visits to cover all areas of proposed project [e.g., LUP (land use plan), EPA (environmental protection agency), water, community); preliminary project P&L (profit and loss) and organizational structure.
- **Deliverables:** Full-scale, comprehensive feasibility study and master plan.

After satisfactory completion of the above phases it is possible to start the project design and planning.

Typical project life cycle

A typical project goes through several phases before it is implemented and operative:

- **Initiation**
- **Planning**
- **Execution**
- **Operation and maintenance**

Some clients/projects can skip phases or integrate several phases.

It is important to understand how to approach a project and ensure the most important elements are maintained regardless of the chosen process/steps.

Initiation

Conceptual design and planning

Generic design and planning of the project including all the aspects relevant to investors' decision making and contract signing.

- **Goal:** To present a detailed proposed project outline.
- **Common content:**
  - Conceptual design
  - Preliminary logistic planning
  - Preliminary work planning
  - Preliminary risk assessment and plan
  - Preliminary cost estimates
  - Conceptual plans
- **Deliverables:** Full-scale, comprehensive feasibility study and master plan.

PROJECT PLANNING AND CONSTRUCTION

Planning

Detailed design and planning

Detailed planning of the project implementation, management and supervision.

- **Goal:** Detailed project design required to facilitate procurement and construction.
- **Common content:**
  - Detailed design
  - Detailed logistic planning
  - Detailed plans
  - Subcontractor's survey and evaluation
  - Final design and planning
- **Deliverables:** Comprehensive project plan, including all items mentioned above, to ensure that project meets client expectations (with focus on time and budget).

Execution

Supervision of the process and management of construction and subcontractors; commissioning the system.

- **Goal:** Deliver an operative project within the specified time frame and budget.
- **Common content:**
  - On-site preparation works
  - Logistic plan execution
  - Installation and commissioning
- **Deliverables:**
  - Operative project on-time, on-budget and at desired quality.
  - Project handover to investors and operators.

Project installation and initiation

This section describes the project implementation operations, emphasizing the link between the farm agricultural operations and the drip system installation, including the planting schedule, machines, manpower, etc.

The implementation process in the field is designed for a maximum rate of 10 ha per day. This requires good planning and high efficiency during execution. Coordination is required between soil preparation, irrigation system installation and the planting process.

Project installation and field preparation time flow

The following diagram illustrates the timing of each operation in subsequent order.

Irrigation system installation process performed by the provider:

Irrigation head	Main line	Valves	Sub-main	Pressurization + sub-main flushing	Field capacity irrigation	Germination irrigation	Finalizing installation (fertigation station + automation)

Soil preparation and planting process performed by the client's workforce:

Soil preparation	Trench opening	Preparations for planting	Furrowing + dripperline insertion + basal fertilizers	Planting + covering	Fertigation + irrigation scheduling

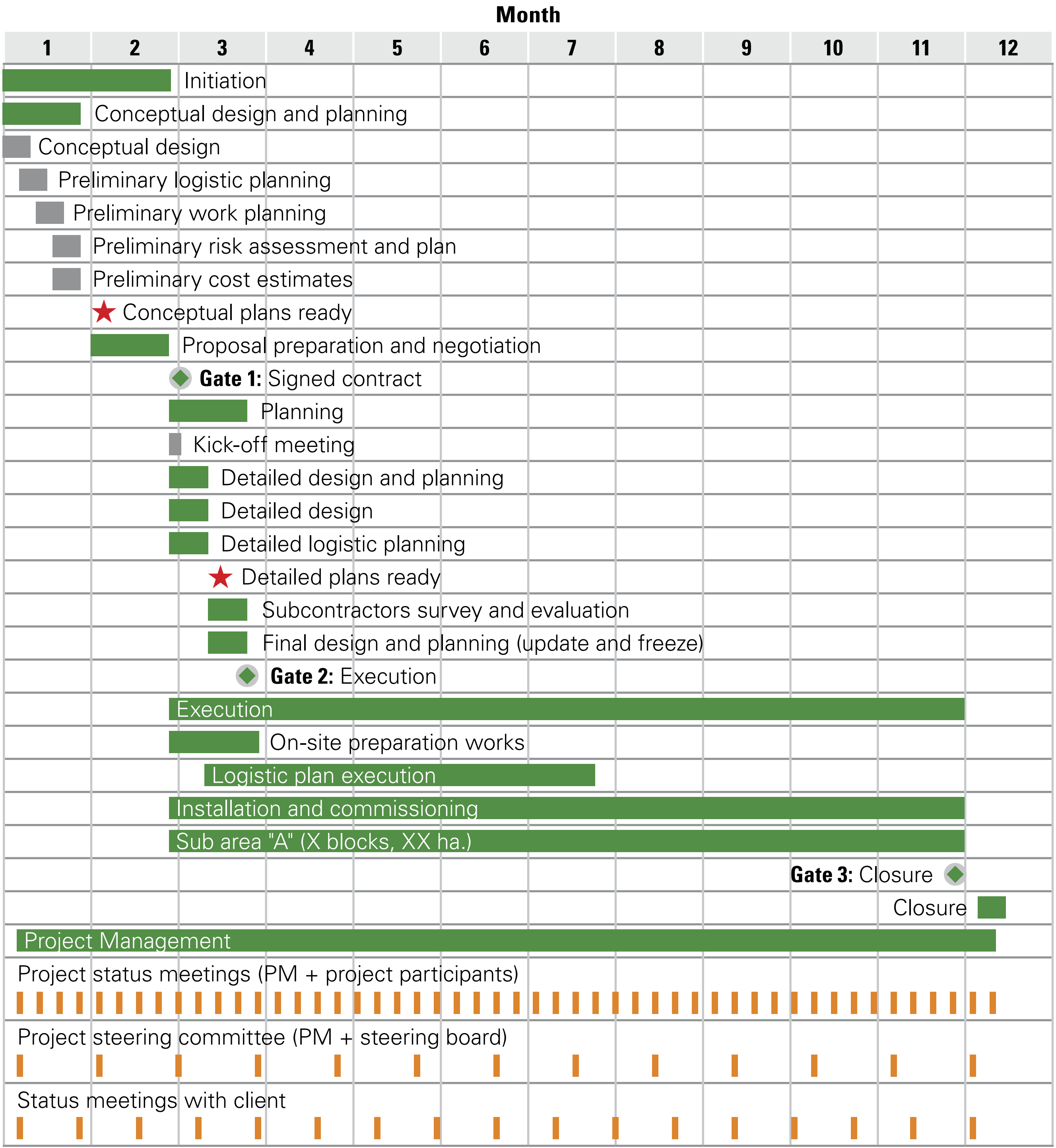
Operation and maintenance

Development of procedures and provision of training to ensure that best results are achieved; provision of any support required to ensure long-term project success and sustainability.

- **Goal:** On-going support and management to achieve annual and long-term project goals.
- **Common content:** All routine and ad-hoc activities required to ensure on-spec project operation.
- **Deliverables:** Training and capacity building, reports and procedures required to ensure successful operation, and giving investors access to desired auditing and control parameters.

PROJECT PLANNING AND CONSTRUCTION

Typical project schedule



CASE STUDIES

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CASE STUDIES

Netafim™ regularly keeps track of the projects it establishes around the globe. Over the years a significant amount of useful data has been gathered.

Six of the many sugarcane projects established by Netafim™ and monitored over the last years are presented in this chapter. The projects represent a variety of site locations, sizes and conditions. Each project faces different challenges according to the site's conditions and limitations, and the grower's goals.

In some of the projects presented, other irrigation methods are used alongside drip irrigation, providing factual comparative data regarding the efficiency of each irrigation method under similar conditions.

The data presented in this chapter are actual and precise.

Examples of implementation:

Large-scale system delivers superior results over time

Client	Royal Swaziland Sugarcane Corporation
Implementation date	1997
Region/country	Simunye, Swaziland (northeast Swaziland)
Total growing area	22,320 ha (11,349 ha drip irrigated)
Current Netafim™ irrigation system	Subsurface drip irrigation (SDI)
Other deployed irrigation methods	Sprinklers, furrow, center pivot (CP)

About the client

The Royal Swaziland Sugarcane Corporation (RSSC) has been growing sugarcane in Simunye since 1958. One of the largest sugarcane growers worldwide that relies almost entirely on subsurface drip irrigation, RSSC began implementing drip over a decade ago. The company's fields are located in a semi-arid climate, with rainfall of 600-700 mm, primarily in the warm summer months. This amount of rainfall supplies just 25-40% of the water requirement for sugarcane. RSSC replants 10% of its fields annually to prevent a decline in yield. Some 50% of its fields are irrigated by subsurface drip, 33% by furrow, 14% by sprinklers, and 3% by center pivot.

Project challenges

- Reducing sugarcane production costs
- Increasing sucrose content
- Increasing yields
- Providing extra water for expansion
- Improving water use efficiency (more tons of cane per mega liter)
- Cutting fertilizer losses through leaching and runoff
- Reducing labor costs and night shift work
- Increasing level of automation

Netafim's solution

Initially installed in 1997, the RSSC project is one of Netafim's largest to date. During the first few years of the project, a Netafim™ expert was continuously on-site to ensure effective implementation and technology utilization.

Solution details:

Planting pattern	dual row 1.4 m x 0.4 m or 1.5 m x 0.4 m
System layout	1.8-1.9 m between dripperlines
Dripperline specifications	RAM light then DripNet PC™ 16 mm, either 1.6 l/h at 0.92 m between drippers or 1.0 l/h at 0.6 m between drippers

Results

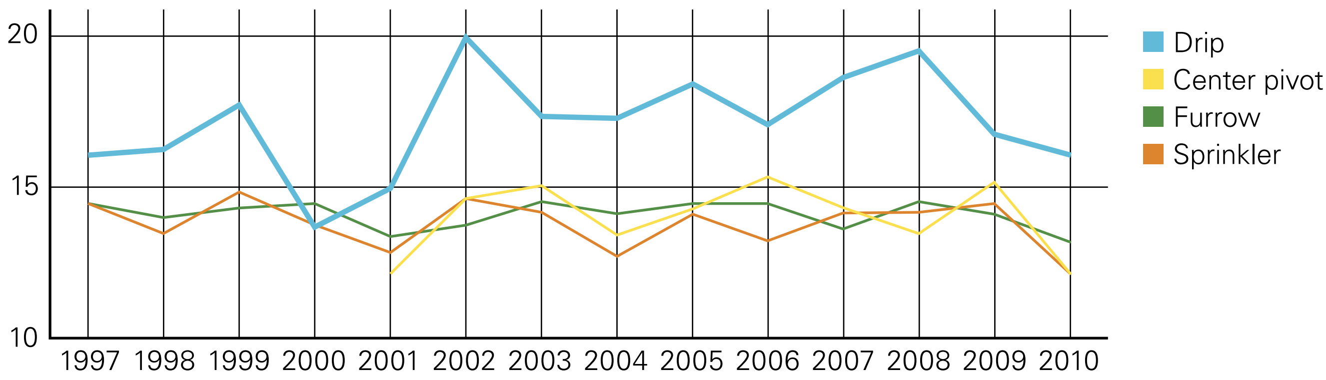
Average annual yield (ton/ha)	
All irrigation methods	106.2
Drip irrigation	140.0

Total Growing Area by Irrigation Type (per project)

Irrigation Type	Simunye		Mhlume		RSSC Group	
	ha	%	ha	%	ha	%
Drip	9166.4	72.1	2182.1	22.7	11348.5	50.8
Furrow	1151.8	9.1	6092.7	63.4	7244.5	32.5
Sprinkler	2038.3	16.0	1063.4	11.1	3101.7	13.9
Center Pivot	357.9	2.8	267.1	2.8	625	2.8
Total	12714.4		9605.3		22319.7	

Sucrose Yield of Mhlume Estate by Irrigation Type

(Sucrose ton/ha)



(Source: Dr. Leonard Sive Ndlovu, the Royal Swaziland Sugarcane Corporation)

CASE STUDIES

Comprehensive solution increases yields and water productivity

Client	Agrovale
Implementation date	2007
Region/country	Juazerio, state of Bahia, Brazil (Sao Francisco Valley, northeastern Brazil)
Total growing area	16,000 ha (3,080 ha drip irrigated)
Current Netafim™ irrigation system	Subsurface drip irrigation (SDI)
Other deployed irrigation methods	Furrow, center pivot (CP)

About the client

Agrovale is a leading Brazilian producer of sugar, ethanol and bio-energy. Located in northeastern Brazil, Agrovale was founded in 1972, and started harvesting cane in 1980. Agrovale is located 370 meters above sea level in the lower-middle part of the Sao Francisco River Valley in the municipality of Juazeiro, in the state of Bahia. The Sao Francisco River is the major source of water for the valley, which is renowned for its productive soil. The region's climate is hot and semi-arid, with annual average rainfall of 540 mm, average year-round temperature of 26°C (78°F), and an average number of 300 sunny days per year. The rainy season takes place during the summer, with average rainfall typically higher during the first half of the year.

Project challenges

- Reducing production costs
- Increasing yield and number of ratoons
- Improving water productivity via increased uniformity and decreased water losses
- Enhancing fertilizer application efficiency
- Enabling greater system management flexibility
- Reducing soil salinization risk

Netafim's solution

Netafim™ installed a subsurface drip system designed for 7-8 ratoons in accordance with the expected crop cycle. The project included an end-to-end irrigation solution - from pumping water from the reservoir to transferring the water through main and sub-main pipes to the in-field drip system. Netafim™ also provided ongoing agro-technical support to ensure the system's success.

CASE STUDIES

Solution details:

Planting pattern	dual row 1.4 m x 0.6 m
System layout	2.0 m between dripperlines
Dripperline specifications	Dripnet PC™ 16 mm, 1.0 l/h, 0.6 m between drippers

Results

	Annual average		
	Yield* (ton/ha)	**Water productivity (kg/m³)**	**Water use (ton/ha/year)**
Drip irrigation	139.8	10.71	1,303
Center pivot	107.6	7.79	1,385
Furrow	100.1	6.74	1,402

*Drip irrigation recorded significantly higher yields compared to CP and furrow irrigation in the first and second ratoons.

Mega project turns virgin soil into ethanol in 3 years

Client	Maple Etanol S.R.L.
Implementation date	2007
Region/country	Piura, Peru (northern coastal region)
Total growing area	7,800 ha (all drip irrigated)
Current Netafim™ irrigation system	Subsurface drip irrigation (SDI)
Previous irrigation methods	Furrow, center pivot (CP)

CASE STUDIES

About the client

Maple Etanol, the Peruvian subsidiary of Maple Energy, is an integrated energy company publicly traded in London and Lima. The company's flagship initiative was to produce ethanol based on the planting, harvesting and processing of 7,800 hectares of sugarcane in the Piura region of Peru. Located on Peru's northern coast, the region maintains a highly favorable agricultural climate enabling year-round planting, cultivating and harvesting of sugarcane. Maple chose to implement a drip irrigation system in order to minimize water requirements while delivering optimal yields.

About the project

The $280-million greenfield project, one of the largest of its kind worldwide, was launched in 2007. By 2011, over 7,800 hectares of three sugarcane varieties, capable of producing up to 35 million gallons of ethanol, had been planted with drip irrigation. The project utilizes modern farming techniques and automation, including extensive use of drip irrigation, to increase yields and cut costs.

Project challenges

- Setting up a drip irrigation system in virgin soil to grow sugarcane that would be converted into ethanol in 3-4 years
- Maintaining consistent production for supplying the ethanol plant, which has a processing capacity of 55,000 tons of sugarcane per day
- Achieving 100% ethanol production, which has been implemented in only a few plants worldwide
- Bringing professional, logistic and operational capabilities to a remote location

Netafim's solution

Netafim™ accompanied the project from inception, working hand-in-hand with Maple personnel and consultants.
Netafim™ installed a comprehensive irrigation system, starting with pumping water from the Chira River into two operational reservoirs. The water was then transferred through main and sub-main pipes to the in-field drip system.
In addition, Netafim™ installed fully-automated Nutrigation™ systems for applying nutrients via its drip irrigation system.

Solution details:

Planting pattern	dual row 1.5 m x 0.4 m
System layout	1.9 m between dripperlines
Dripperline specifications	Dripnet PC™ 16 mm, 1.0 l/h, 0.5 m between drippers

Results

First-year harvest (2012): 900,000 tons
First-year average yield: 140-180 ton/ha
Project completion: 3 years

CASE STUDIES

Drip consistently delivers better yields

Client	Rai Nongmakhamong
Implementation date	2006
Region/country	Danchang district, province of Suphanburi, Thailand
Total growing area	560 ha (average 60 ha/grower)
Current Netafim™ irrigation system	Subsurface drip irrigation (SDI)
Other deployed irrigation methods	Furrow




About the client

Rai Nongmakhamong is a 560-hectare sugarcane project in which 60-ha plots are divided among several growers.

Nongmakhamong is located in the Danchang district of Thailand's Suphanburi province. The region's major water source is the Krasiew Canal and the Krasiew Dam.

Since traditional furrow irrigation systems produced low yields and often led to salinity problems, area growers sought an easy-to-install and easy-to-operate solution.

Project challenges

- Increasing yields and the number of ratoons between replanting
- Shortening irrigation duration and improving germination
- Cutting energy and labor costs
- Improving fertilizer application and reducing its usage
- Improving soil sustainability and reducing the risk of soil salinization

Netafim's solution

Netafim™ designed, customized and installed a subsurface drip system to suit local conditions and grower preferences.
The solution consisted of a complete drip irrigation system including head control, filtration, valves, main and sub-main pipes, and dripperlines.

Solution details:

Planting pattern	dual row 1.4 m x 0.4 m
System layout	1.8 m between dripperlines
Dripperline specifications	Dripnet PC™ 16 mm, 1.0 l/h, 0.5 m between drippers

Results

The average annual yield with drip irrigation over the years 2006-2012 was of 113 ton/ha compared to an average of 50 ton/ha achieved by furrow.

As a result of the significant increase in yield, all new sugarcane fields in the project are now irrigated via SDI.

Smallholders double yields and achieve rapid ROI

Client	Lam Son
Implementation date	2007
Region/country	Tho Lam commune, Tho Xuan district, province of Thanh Hoa, Vietnam
Total growing area	16,000 ha (29,000 growers; average 0.55 ha/grower)
Current Netafim™ irrigation system	Subsurface drip irrigation (SDI) (300 ha); surface drip irrigation (500 ha)
Other deployed irrigation methods	Furrow

CASE STUDIES

About the client

Established in 1980, the Lam Son Sugar Joint Stock Corporation is Vietnam's largest sugar manufacturer. The company manufactures and markets sugar, alcoholic and non-alcoholic drinks, as well as other sugar-based products and animal feed. Lam Son's 16,000 hectares of sugarcane fields in the Thanh Hoa province primarily belong to individual farmers and cooperatives, and is the home of the company's manufacturing plant. Located in northern Vietnam, Thanh Hoa enjoys a climate suitable for growing sugarcane (19.8° latitude, 1,700 mm of rainfall per year).

Although the province's average rainfall level is high, it is concentrated during the summer, while sugarcane needs to be irrigated after the spring planting season - when there is almost no rainfall - and during its development period.

In 2007, Lam Son installed initial SDI drip systems for a 104-ha pilot project, which was expanded over the next few years. In 2011, Lam Son began using surface drip systems for smallholders - growers with small sugarcane farms of 1-10 ha - who sell their produce to the company.

Project challenges

- Implementing effective solutions for smallholder plots (up to 10 ha)
- Overcoming limited water and power sources
- Achieving rapid return on investment (ROI)

Netafim's solution

Netafim™ supplied dripperlines, filters and air valves, while a local vendor supplied pumps, PVC main and sub-main pipes, fittings, and manual valves. The system was designed for sloped topography, and operates with water pumped from deep wells by diesel pump.

Solution details:

System layout	1.2 m between dripperlines
Dripperline specifications	Dripnet PC™ 16 mm, 1.0 l/h, 0.5 m between drippers

Results

Annual average yield: 100-110 ton/ha compared to 50-55 ton/ha achieved by furrow
System deployment speed: Rapid, due to implementation of surface drip irrigation system
Irrigation scheduling: Flexible day/night
Sugarcane germination: High level due to implementation of drip

CASE STUDIES

Nutrigation™ system ensures precise nutrient and water delivery

Client	Paul Villis
Implementation date	2008
Region/country	Ayr, North Queensland, Australia
Total growing area	400 ha (18 ha drip irrigated)
Current Netafim™ irrigation system	Subsurface drip irrigation (SDI)
Other deployed irrigation methods	Furrow

About the client

Paul Villis is a leading sugarcane grower near the town of Ayr, located in the shire of Burdekin in North Queensland.
Most local sugarcane farms in the region irrigate by furrow; Villis was one of the first growers to shift to drip irrigation. Sugarcane fields in the area, Australia's sugar capital, are irrigated with groundwater and water from the Burdekin Dam. Water efficiency currently is not a high priority in the region; however, it is likely that regulators eventually will address the inefficient use of water. In addition, dry spells and droughts in the region are expected to make the efficient use of water and resources a necessity.

Project challenges

- Producing more yields with less water, fertilizer, electricity and labor
- Improving resource and land productivity
- Increasing in-field management and easily controlling activity from any location
- Applying nutrients more frequently and in smaller quantities to reduce waste

Netafim's solution

Sold by Bartec Irrigation Company and installed by Villis, the subsurface drip irrigation system was designed and customized by Netafim™ to suit local conditions and grower needs. Offering increased reliability and longevity, the comprehensive, medium-walled dripperline solution included Netafim's NMC controller and the IrriWise™ monitoring system with NetaSense soil moisture sensors. Netafim™ also provided ongoing agro-technical training and system support to ensure success.

Solution details:

Planting pattern	Dual row 1.4 m x 0.4 m
System layout	1.8 m between dripperlines
Dripperline specifications	DripNet PC™ 22 mm, 1.0 l/h, 0.3 m between drippers

Results

- **Average annual yield:** Over 30 ton/ha more compared to furrow irrigation during each of the first four years, representing an annual increase of 25% and nearly 13 ton/ha of sugar.
- **Water usage:** 50% lower compared to furrow irrigation.
- **Nitrogen application:** Lower compared to furrow irrigation due to precise application of fertilizer and reduced leaching.

	Annual yield (ton/ha)					
	2009		2010		2011	
Irrigation method	Cane	Sugar	Cane	Sugar	Cane	Sugar
Drip	190	30	185	26	145	21
Furrow	160	25	150	22	110	17

"We planted a new sugarcane block in early 2008. We decided to use subsurface drip irrigation mainly because our traditional furrow was not delivering the results, and, as we knew from our previous vegetable farm, drip is far easier to manage. Another reason for converting to drip was that we wanted to apply nutrients in small, but frequent, quantities."

Paul Villis

APPENDIX 1

Frequently asked questions (FAQ)

How much does a drip irrigation system cost per hectare of sugarcane?
This is very variable and depends on the following three factors:

- **Conveyance of water from source to the field:** normally this is the most expensive component of the irrigation system. It depends on the distance and elevation the water has to be conveyed by the pipelines.
- **Peak crop water demand:** Amount of water needed to apply to meet the peak crop evapotranspiration requirements during the crop peak demand. This is a function of prevailing climate conditions, crop canopy cover and efficiency of the irrigation system.
- **Other considerations:** The land topography of the design area - whether flat or undulated - and the soil texture, which determines the emitter spacing. For example, sugarcane on sandy soils requires closer emitter spacing while clayey soil requires wider emitter spacing that will have a significant impact on the system cost per unit area.

(See Economic analysis, page 11).

Why choose drip and not other irrigation methods that are apparently less expensive?
Since the drip technology was invented by Netafim in 1965, it has proved to be technically feasible and economically viable for a broad range of environments and crops, including sugarcane. Drip has been found to increase cane yields and number of ratoons as well as improving the sucrose level.
Drip technology also allows significant saving in water, fertilizers, labor and energy required for pumping water. In the long run, economic calculations show that drip is the most suitable system for modern sugarcane agriculture with higher economic returns.
(See Choice of irrigation method, page 15).

What should I do to guarantee the success of a drip sugarcane project?
The success of the sugarcane project depends on few crucial factors: Good agriculture practices like proper soil preparation, selecting the most suitable varieties for irrigation and fertilization, planting time, quality planting material, quality drip system components and irrigation design and timely harvesting.
For each project, Netafim provides the most customized solution package for the local farm conditions, climate and management level of the client, which obviously differ from one project to another.
(See Key factors for project success, page 39).

As a sugarcane grower, should I use subsurface or surface drip system?
Subsurface drip irrigation has been shown to have many agro-technical advantages for sugarcane growers, besides the regular drip features. There is no need to recollect the dripline before every harvest cycle, the driplines are protected from agro-machinery damage, it permits using a thin wall dripline that significantly affects the cost and it applies the water and the fertilizers directly to the sugarcane root zone. Finally, the grower can apply all the crop agro-machinery activities without interfering with the day-to-day irrigation system protocols.
(See Dripperline selection and layout design, page 33).

What is the lifespan of the drip system for sugarcane and after how many years will I have to renew it?
The accumulated field experience has revealed that sugarcane cultivated with a subsurface drip irrigation system can continue up to eight and/or more ratoons before the field is renewed for a new crop cycle. During the renewal of the field for a new plant crop, all the hydraulics such as pipes, pump, filters, etc., remain intact on the field for further use and only the dripline must be replaced. This represents around 50% of the total system cost per unit area.
(See Economic analysis, page 11).

APPENDIX 2

The symbols used in this document refer to the following:

WARNING
The following text contains instructions aimed at preventing bodily injury or direct damage to the crops and/or the irrigation system.

CAUTION
The following text contains instructions aimed at preventing unwanted system operation, installation or conditions that, if not followed, might void the warranty.

NOTE
The following text contains instructions aimed at emphasizing certain aspect of the operation or installation of the system.

ACID HAZARD
The following text contains instructions aimed at preventing bodily injury or direct damage to the crops and/or the irrigation system in the presence of acid.

ELECTRICAL HAZARD
The following text contains instructions aimed at preventing bodily injury or direct damage to the irrigation system components in the presence of electricity.

SAFETY FOOTWEAR
The following text contains instructions aimed at preventing foot injury.

PROTECTIVE EQUIPMENT
The following text contains instructions aimed at preventing damage to health or bodily injury in the presence of fertilizers, acid or other chemicals.

EXAMPLE
The following text provides an example to clarify the operation of the settings, method of operation or installation.
The values used in the examples are hypothetical. Do not apply these values to your own situation.

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