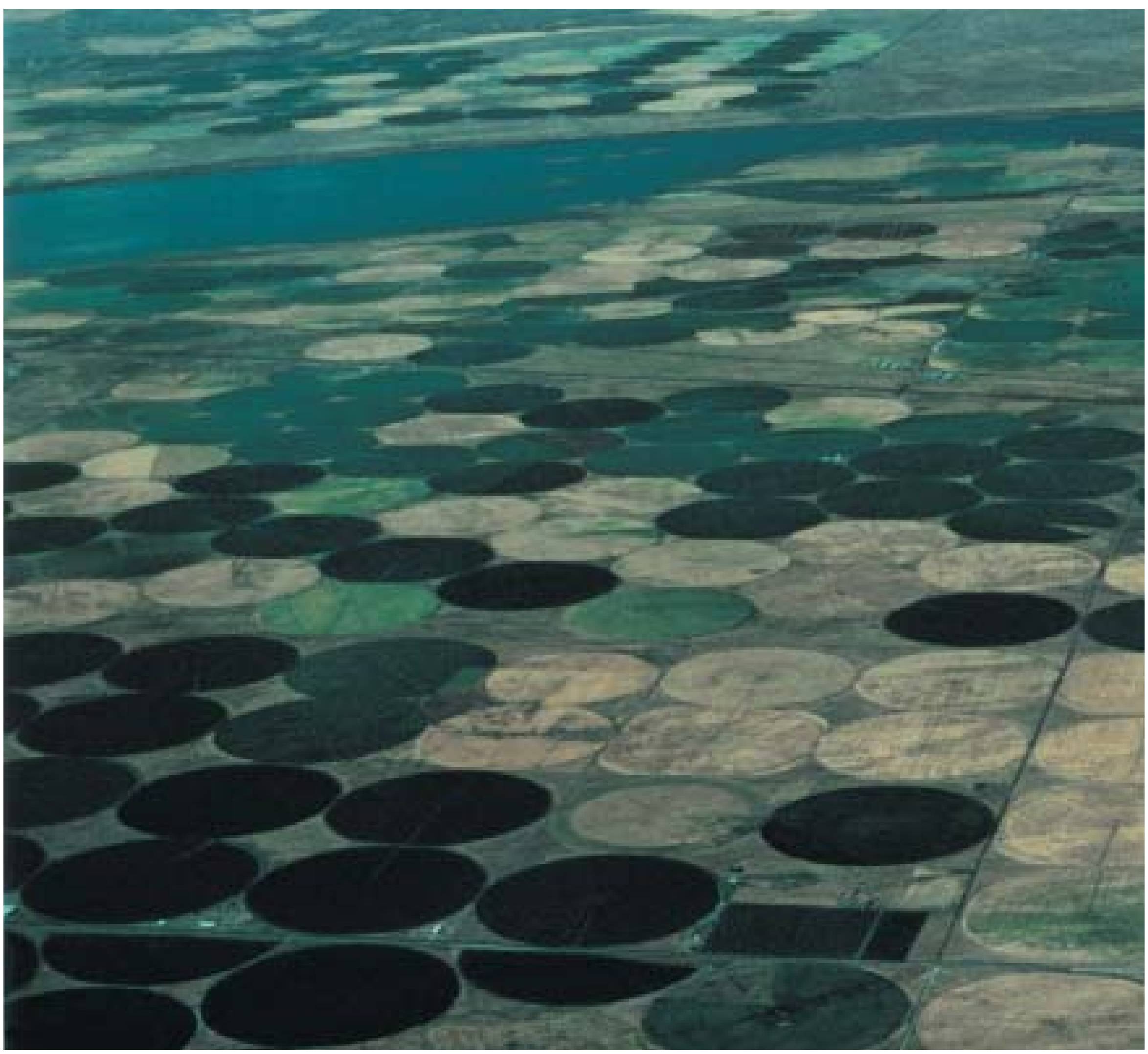
CIRCLES OF LIFE

CONTENTS__

Front Cover: Sugar cane field in South Africa.
Below: Columbia River Basin near Washington-Oregon border.
With an arid to semi-arid climate, this desert blooms under pivots.



GROWING MORE FOOD WITH LESS WATER

"A PARTICULARLY DIFFICULT CHALLENGE WILL BE TO IMPROVE THE EFFICIENCY OF AGRICULTURAL WATER USE TO MAINTAIN CROP YIELDS AND OUTPUT GROWTH, WHILE AT THE SAME TIME ALLOWING REALLOCATION OF WATER FROM AGRICULTURE TO RAPIDLY GROWING URBAN AND INDUSTRIAL USES. HOW THIS WILL BE MANAGED COULD DETERMINE THE WORLD'S ABILITY TO FEED ITSELF."

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OVERVIEW

Growing more food with less water is becoming a critical challenge for agriculture across the world in the 21st century. Rising populations and increasing water scarcity are creating dual burdens on agriculture. First, a larger population needs more food and fiber. Second, agriculture has a diminishing supply of irrigation water to meet these rising demands.

Improving how water is delivered to farms and put to use in fields is essential for meeting the changing needs of global populations. Improved water usage can enhance both food security and human nutrition. Tremendous inefficiencies in global irrigation methods are numerous and difficult to manage. Addressing these problems creates many opportunities for progress and economic growth, especially in the developing world.

Some environmental problems have been attributed to irrigation. Overuse of water can indeed cause shortages in river basins or deplete an underground water supply. Overwatering and lack of proper drainage can load soils with salt, damaging the land's productive capacity. Improperly applied crop chemicals can also leach into groundwater or pollute surface water.

Irrigated agriculture is becoming more and more important, as the nutritional needs of the world grow with our population. Yet, irrigated agriculture faces many formidable challenges. However, with modern irrigation management, advanced agronomic practices, and more refined decision-making systems, countries facing these challenges can create a more productive and profitable agricultural base. Societies that capitalize on these opportunities will meet the nutritional needs of their populations and at the same time they can become more competitive in the global marketplace.

At the most basic level, the way that people take care of water must change before they can realize other benefits of enhanced agriculture. To grow more food, the water farmers use must be managed more carefully.

Mechanized irrigation saves more energy and uses less water and labor than other forms of irrigation. By using irrigation equipment that is more durable and efficient, farmers are able to increase their revenue, their crop yields, and even the land area they farm. Mechanized irrigation can also help solve other problems, such as waterlogged soils, salinity, and water contamination. Modernizing irrigation practices, then, has both economic and environmental benefits. Mechanized irrigation is an excellent place to begin as countries seek ways to grow more food with less water and human toil.

Above left: Many varieties of flowers are well suited for pivot irrigation, whether grown in East Africa, Ecuador, or France – as in this photo.
Above right: Different crops can be grown under a single pivot by dividing the crop circle into segments as in this field in Kenya.

"AT THE MOST BASIC LEVEL, THE WAY THAT PEOPLE TAKE CARE OF WATER MUST CHANGE BEFORE THEY CAN REALIZE OTHER BENEFITS OF ENHANCED AGRICULTURE. TO GROW MORE FOOD, THE WATER FARMERS USE MUST BE MANAGED MORE CAREFULLY."

IRRIGATION TECHNOLOGY

Evolution of Irrigation Management __ To gain perspective on the irrigation methods available to farmers today, it will be useful to trace the historical development of irrigation. Egypt provides a nice case, since Egyptian civilization understands itself truly as the gift of the River Nile.[1]

The natural inundation and recession of the Nile waters determined the seasonal rhythms of ancient Egypt, and provided the opportunity for farmers to sow their seed on the wet soil immediately after the river waters receded. In this 'eotechnic' model of natural irrigation growers do not control the inflow or outflow of water.

An image of the so-called 'Scorpion' King (ca. 3100 BCE) performing the ceremonial digging of an irrigation ditch or levee is the first evidence of artificial irrigation in Egypt. When a flood was unusually low, ancient Egyptian farmers would cut sluices into the levees; when a flood was unusually high, they would reinforce the levees. The farmers also divided one natural flood basin into several artificial basins by building transverse earthen dikes. Canals connected one basin to another, thus allowing a high level of control: irrigators could optimize their water usage by fully irrigating one artificial basin before sending the water on to the next basin. This 'paleotechnic' method of irrigation thus compensated for floods that were insufficient and protected from floods that were overabundant.

It should be noted that in Pharaonic Egypt, irrigation was not administrated by some high official who implemented a rational public policy, as a modern-day Minister of Water might. Ancient Egyptian government lacked the necessary local infrastructure outside of the capital for the pharaoh to impose his directives throughout the country. In fact, from Greek and Roman times through the nineteenth century, irrigation in Egypt was organized and maintained locally.

Above Left: Sprinkler packages should be customized to fit terrain and soil conditions. Rotating sprinkler heads, as in this pivot in the Pacific Northwest United States, are well-suited to hilly terrains and heavy soils, which have a slow infiltration capacity.
Above Right: Since they began irrigating the Nile Valley over 5,000 years ago, Egyptians have made major contributions to the development of irrigation technology.

EMPLOYING APPROPRIATE MODERN IRRIGATION TECHNOLOGY IN DEVELOPING COUNTRIES IS THE WAY FOR PROGRESS: INCREASING AGRICULTURAL YIELDS, IMPROVING NATIONAL ECONOMIES, AND EMPOWERING FARM WORKERS TO BECOME MORE PRODUCTIVE WITH THEIR WORKTIME.

Besides the water conveyance network of levees, dikes, sluices, and canals, two other irrigation technologies in ancient Egypt deserve mention – the shaduf and the saqiya. The shaduf, which originated in Mesopotamia, is a lever with a water bucket tied to the end of a long pole, which the user pulls down to lift water up, and out of a pond or river. This machine is better than a mere bucket, but it is still very labor-intensive and inefficient. Using a shaduf, three men could only water a quarter-hectare in a day. The saqiya is a more advanced machine also from Mesopotamia which uses animals to pull up from a well or river a belt of ropes with water-filled jugs. In one day, a saqiya could irrigate eight to ten hectares.

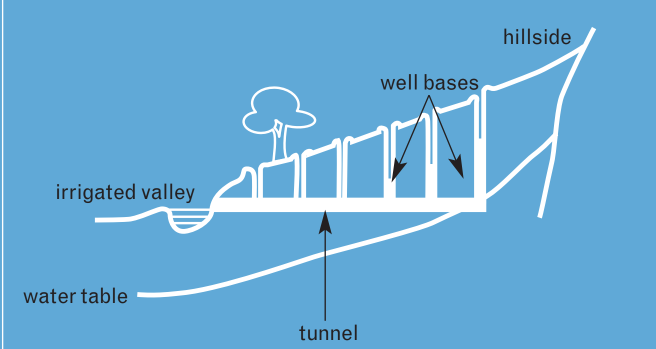
The kanat system of hand-dug wells also deserves mention, as it has been used since time immemorial up to the present time, although not in Egypt. These chains of wells would be dug in a line up a hillside. The bases of the wells are connected by a tunnel which provides a continuous channel from deep within the hill to the fields near the bottom of the hill. The 'mother well,' near the top of the hill, taps the underground water table and in some cases is hundreds of meters deep. Perhaps as many as 30,000 kanats have been dug in Iran, and it is estimated that over 20,000 of them are still operational.[2] (See illustration of kanat below.)

This brief treatment of ancient irrigation should give some idea of the complexity and effectiveness of ancient methods. In fact, irrigation predates recorded history, and developed not only in ancient Egypt but also in ancient China, Peru, Persia, and India. The methods described above are just a few of the most important traditional means by which innovative farmers brought water to their fields.

Across much of today's world, irrigation methods are similar to techniques used as far back as 6,000 years ago. Some farm families still move water by hand, conveying it through earthworks, down furrows, and across the surface of small plots of land. **Although innovative in ancient times, when compared to modern irrigation technologies, traditional irrigation uses far more water and human resources than is necessary. Employing appropriate modern irrigation technology in developing countries is the way for progress: increasing agricultural yields, improving national economies, and empowering farm workers to become more productive with their work time.**

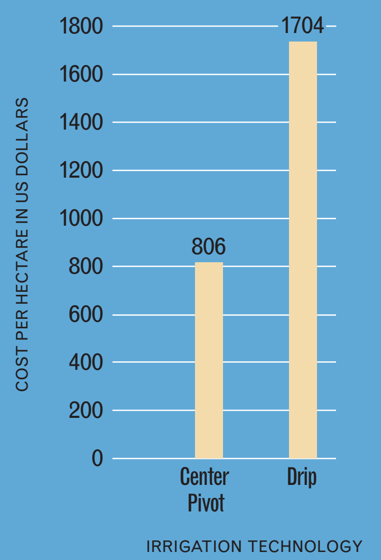
1 Butzer, Karl W. "Irrigation," *in The Oxford Encyclopedia of Ancient Egypt*. Vol.2, ed. Donald B. Redford (Oxford: University Press, 2001), 183-188.
2 Cantor, Leonard M. *A World Geography of Irrigation.* (Edinburgh: Oliver and Boyd, 1967), 14-18.

ILLUSTRATION OF KANAT SYSTEM



Below: This photo illustrates the straight rows of a field irrigated by a Valley linear move system. Linears are especially suited to farms where land prices are particularly high.

INITIAL INVESTMENT COST COMPARISON



(Based on a field size of 50.6 hectare)

O'Brien, Daniel; Rogers, Danny; Lamm, Freddie; and Clark, Gary. "An Economic Comparison of Subsurface Drip and Center Pivot Sprinkler Irrigation Systems." *Applied Engineering in Agriculture.* 1998. Vol.14(4):391-398

Development of Drip Irrigation__ Drip irrigation was first introduced in 1917 by Dr. Lester Kellar to irrigate avocados in California. In the 1960's this method began to be widely used in Israel, where the desert conditions and limited water supply created the need for a water-saving agricultural irrigation system. Drip irrigation allows water to drip out from small emitters to plants' roots directly. The water travels at low pressure through a network of perforated plastic tubing installed on or below the surface of the soil. Drip irrigation has been described as the "leaking faucet" technique since it applies water slowly over a long period of time.

Drip irrigation systems deliver water directly to the root zone of the plant where it is most beneficial. If properly managed, drip systems improve yields and reduce the application of fertilizer and chemicals. They also require less water and allow for easier field access than furrow and flood irrigation systems. Drip systems are particularly suited to the production of vegetable crops that are grown on raised beds, including strawberries, carrots, and tomatoes.

Drip irrigation requires rather intensive management by operators and a sizable initial capital investment. Drip system operators inspect their fields frequently for problems that affect watering uniformity such as plugs and leaks. Filters used with drip irrigation to keep particles from clogging the emitters must be flushed regularly. Drip irrigation systems are relatively expensive with costs ranging from USD $1,235 to $2,470 a hectare for a basic system.

Development of Sprinkler Irrigation__ Also in the 1950s, sprinkler irrigation was developed. Sections of small pipeline, fitted with vertical tubes topped by sprinklers, were moved into newly planted fields, then removed prior to harvest. In some cases, farmers towed these pipelines by tractor from one field to another.

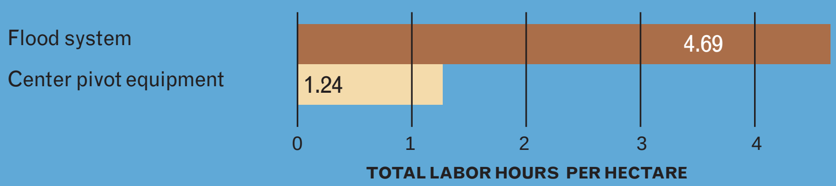
Next came side-roll sprinkler systems. The main water line served as the axis for the wheels, so it was easier to move. However, this method still required considerable labor because the system had to be moved every few hours. Generally, these side-roll, wheel move sprinklers were used only on shorter crops, such as alfalfa, potatoes, sugar beets, and vegetables. Taller crops could not be grown with these systems.

Introduction of Center Pivot Irrigation__ By the middle of the 20th century, agriculture was ready for a better kind of sprinkler system. It was invented in 1952 – the self-propelled center pivot sprinkler. Over that next decade, this new design was gradually accepted as a superior form of irrigation.

The center pivot concept is simple. A long pipeline, attached to a central point, travels over a field in a circle. As it passes over crops, sprinklers spaced along the pipeline emit water, nourishing the crop below.

With flood irrigation, over 4.5 labor hours are required for every hectare of land. Pivots require only 1.24 hours per hectare, that is, 25% as much labor as flood irrigation.

LABOR REQUIREMENTS PER YEAR/PER HECTARE



Labor requirements and cost charts are based on a University of Nebraska study, "Comparison of Irrigation Distribution Systems."

By the mid-60s, center pivots irrigated a wide range of crops in the western and central United States. Valmont founded the center pivot industry and is now the world leader in the manufacturing and development of mechanized irrigation technology. Valley® brand equipment irrigates more than 4 million hectares in over 90 countries. The company's products have been improved through several design generations. Today, the equipment is known for being simple to operate, highly reliable, long lasting, and extremely precise in operation.

Versatility and Crop Production__ Center pivots are used in widely varying climates and topography. The equipment waters a wide range of soil types, from extremely sandy to fine-textured clay soils. It can draw on many water sources, using surface water, aquifer (ground water), saline water, and wastewater.

When first introduced, the equipment was often installed on hilly land in dry regions. In these areas, water was accessible, but surface irrigation was not possible. As this low-cost land was developed, it produced top yields within one to two years.

Today, center pivots in many cases are replacing surface irrigation on flat lands. These farms are being converted to mechanized irrigation for many reasons. Mechanized irrigation uses 25% to 50% less water than surface irrigation and reduces labor up to 75%. These factors allow farmers to raise crops on more hectares, using roughly the same amount of water and less labor. Mechanized irrigation also allows producers to practice superior farm management.

The technology is also used in rainfed farming regions. Even where annual precipitation often reaches 1,200 mm to 1,500 mm, the timing of rain may not match crop needs. If precipitation is highly variable, pivots protect yields during dry years.

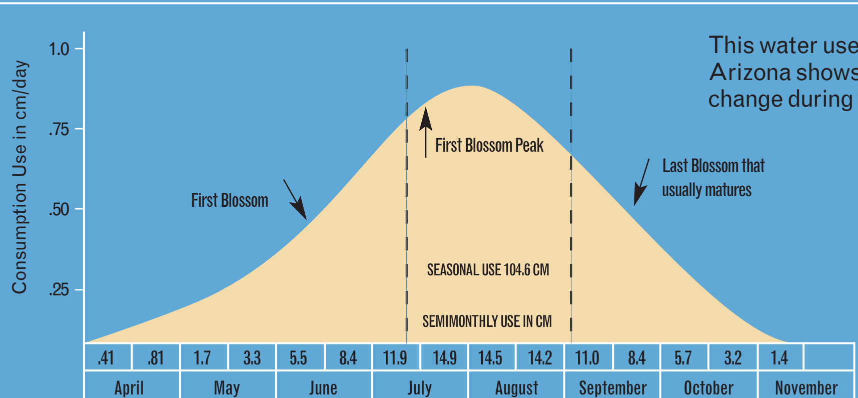
Once mechanized move irrigation has proven itself in a region, its importance grows rapidly. Moisture variability during the growing season is a farmer's biggest risk. With the decreased risk that mechanized irrigation provides, farmers can afford to invest more in their farming operation.

Above Left: Rolling hills are not an obstacle to pivots. The jointed structure functions well on slopes up to 15%.
Above Right: LEPA irrigated cotton field in Texas, USA. LEPA (Low Energy Precision Application) is a technique that integrates cultivation and irrigation practices to optimize water usage efficiency. Water is applied through a 'sock' attached at the end of a hose drop which reaches to the ground.

Higher-Value Cropping Options__ Mechanized move irrigation allows farmers to overcome physical limitations and technical problems involved with the adoption of new cropping systems. With reliable, precision irrigation, farmers have an added economic interest in planting higher value crops. Mechanized move irrigation systems provide farmers with additional benefits by expanding their options for more advanced fertility and pest management programs. New equipment to cultivate, harvest, and store crops also becomes affordable. Whether enhanced crop value comes from more crop harvests per season, development of a livestock sector built around reliable forage and grain supplies, or simply the production of more nutrient-rich, higher quality food, these trends enrich the farm economy and the individual farmer who uses mechanized irrigation.

While farm profit potential is increased by higher-value crop yields, quality, and diversification, mechanized irrigation also improves the system-wide stability of production agriculture. These signs of progress encourage a greater degree of specialization. Enhanced use of specialized knowledge and labor at the local level – in the forms of a vital farm service sector, improved crop management, training in new farming methods, or pursuit of new marketing opportunities – helps create a more diverse, stronger agricultural sector, creating benefits at the regional and macro-economic levels.

This water use information from Arizona shows how crop needs change during the season.



Seasonal Water Use by Cotton

Benefits of Versatility__ Nearly all crops can be irrigated with center pivot or linear irrigation systems. Common field crops grown with this equipment include: wheat, cereals, cotton, maize and other feed grains, oil seeds, and sugar beets. Vegetable crops and fruits can be grown under mechanized irrigation, including melons, berries, potatoes, beans, peas, tomatoes, lettuce, cabbage, carrots, and sweet corn. Because the equipment comes in various heights, even citrus trees, fruit and nut orchards, and tall crops such as sugarcane are raised under mechanized irrigation equipment.

This versatile equipment allows producers to easily control when and how much water is applied. Under surface irrigation, it is impossible for a farmer to apply precise rates of water in varying parts of a field. However, with center pivots, the farmer simply pushes a button to turn the equipment on and off as needed, or to change the rate of water application with great precision.

Application flexibility creates other benefits. Where water is scarce, farmers can plant more than one crop in a field. Half of a field is planted with one crop, such as cotton, while the other half is planted with a crop that uses less water, such as wheat. As the center pivot passes over the crops, less water is applied on the wheat and more is applied on the cotton.

Farmers can also plant and water crops to achieve different maturity dates. This can be important for market crops, such as vegetables. The planting dates are varied to have a constant supply of fresh produce. This gives farmers more options and reduces market risk. Pivots allow farmers to conveniently meet their water needs, based on crop development.

Mechanized irrigation also offers advantages in irrigation timing. Water should be applied when the crop needs it most. With many crops, the maximum yield is determined in early growth stages. For example, with wheat, the potential crop yield is determined when the plants are only a few weeks old. This process happens at a microscopic level. Crop stress in this critical time will permanently limit yield potential. Using a center pivot, farmers simply push a button to water a crop at crucial times in plant development. Under furrow irrigation, such precision in timing or water application is not possible. Late season water needs, when plants are filling fruit or grain, can likewise be met exactly to ensure that the farmer's hard work is not lost due to crop stress at a crucial period of the growing season.

Unlike surface irrigation, center pivots do not require furrows to carry water through the field. Eliminating this tillage saves money and time, plus it also allows the farmer to immediately plant another crop in the field – a key factor in the success of multiple cropping. After one crop is harvested, farmers can prepare the field and seed a new crop. They can then turn on the center pivot and irrigate the field so that the seeds quickly germinate, a benefit that subsurface drip systems cannot offer.

Thus, the advantage in controlling the timing of irrigation not only improves crop yields, it can also help farmers increase the number of crops that they harvest. Both factors multiply potential income.

Upper Left: A 90%-95% water application uniformity can be achieved with proper sprinkler package design. Many variables must be taken into account, including the water needs of the crop, soil intake capacity, the available water pressure, wind, heat, and soil salinity.

Complementary Agronomic Advances__ Delivering water to crops at the optimal time and efficiently applying it in exactly the right amounts are only part of the answer. As irrigation becomes more reliable, farmers become less susceptible to risk because they know the water will be there when they need it.

Optimizing water use should be accompanied by the adoption of complementary agricultural inputs. Unless farmers use improved seed, fertilizers, pesticides, and new cultural practices, in addition to modern irrigation, they will not maximize the potential benefits which modern technology offers. In Pakistan, irrigation farmers using progressive techniques grew yields that exceeded traditional irrigation cropping practices by 250% to 333%. The yield improvements were not due solely to modern irrigation, but also reflected the value of using better crop inputs and cultural practices. (Table 1.)

Table 1. Major Crop Yields in Pakistan	Average yields (100 kg/ha) (Traditional practices)	Average yields (100 kg/ha) (Progressive practices)	Potential Increase
Wheat	13.8	46.0	333%
Seed cotton	6.8	16.6	257%
Rice	18.4	50.6	275%
Maize	13.8	41.4	300%
Sugarcane	294.5	782.0	266%

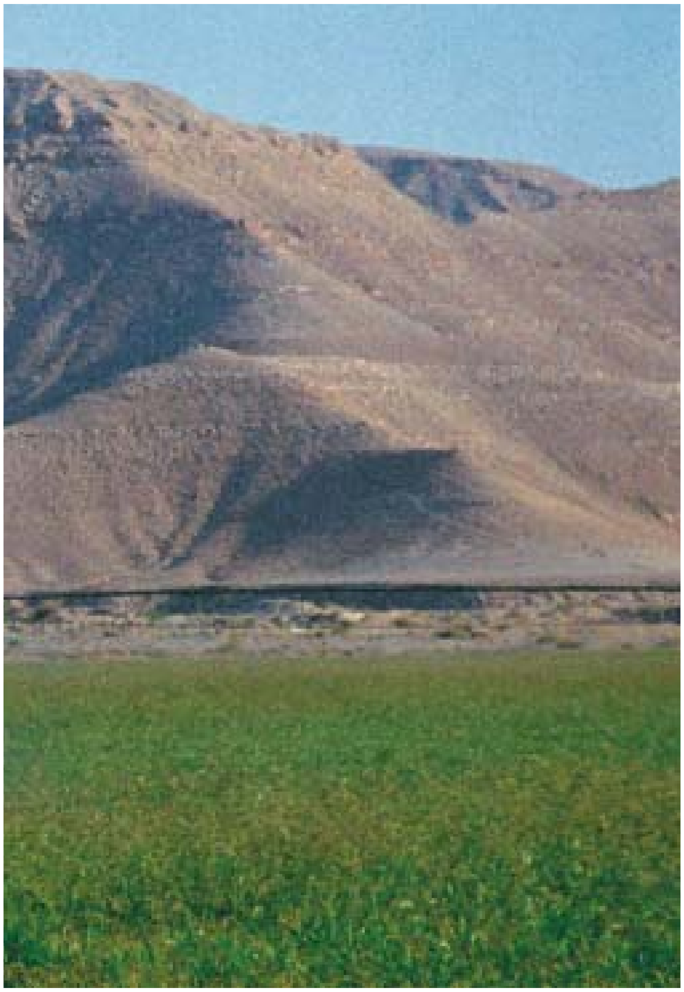
Source: M. Ahmad, PARC

Crop Input Application__ Center pivots and linear move irrigation equipment apply water precisely as do well-managed drip irrigation systems. Precise water application ensures that crops get the right amount of water at exactly the right time, rather than too much or not enough water. The precise water application capabilities of mechanical move irrigation systems can also be used to apply other crop inputs. For example, fertilizer can be mixed with irrigation water and applied during the growing season. Pivots and linears can thus deliver nutrients to crops, as well as water, when the growing plant needs them most.

Applying nutrients during the growing season reduces the need to apply heavy doses of fertilizer before the crop is planted. It is in the early part of the season – when soils lay bare to wind and water – that the risk of erosion is greatest. When the soil washes away, so do fertilizer and crop inputs. Fertilizing plants later in the season, when a crop canopy protects the soil, helps keep fertilizer where it belongs.

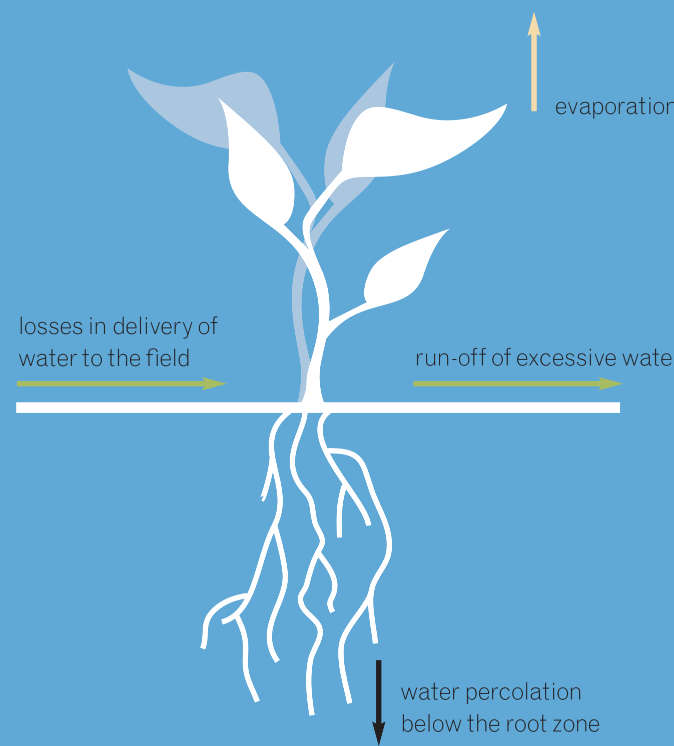
Other chemicals can also be applied through center pivot or linear move irrigation equipment. Farmers can thus treat insect outbreaks or control weeds as they apply irrigation water. Once again, applying chemicals only when they are needed helps keep them in fields and out of aquifers, streams, rivers, and lakes.

Above: Valley Spinner on alfalfa field in Saudi Arabia. Valley offers irrigation solutions for small farms as well as large-scale commercial operations. The Valley Towable Spinner irrigates fields of 1-2 ha and can easily be used on 4 to 6 settings, whether as many small fields or different settings in one field.



WATER LOSSES

Irrigation efficiency is determined by the ratio between the water used by plants and the water applied to the field. This illustration shows where water losses occur.



Population Growth and Food Supplies__ The world population is projected to grow to 7 billion by 2010, up from 5.3 billion in 1990. This is an increase of 32% in 20 years. (Table 2.)

Table 2. Population estimates and projections

Region	Population and Its Density						Growth Rates (% per year)		
	1990		2000		2010				
	million	Inhabitants/km²	million	Inhabitants/km²	million	Inhabitants/km²	1990-2000	2000-2010	1990-2010
Northern Africa*	143	17	178	22	215	26	2.2	1.9	2.1
Sub-Saharan Africa	489	22	653	30	853	39	2.9	2.7	2.8
Asia[1]	3,120	113	3,659	132	4,175	151	1.6	1.3	1.5
Europe	499	102	511	105	513	105	0.2	0.0	0.1
Former USSR	288	13	296	13	305	14	0.3	0.3	0.3
South America	293	16	346	19	397	22	1.7	1.4	1.5
North & Central America	424	19	484	21	538	24	1.3	1.1	1.2
Australia	17	2	19	2	21	3	1.3	1.1	1.2
Oceania	10	12	11	14	13	16	1.8	1.6	1.7
World	**5,283**	**39**	**6,158**	**46**	**7,031**	**52**	**1.5**	**1.3**	**1.4**

* Northern Africa includes Algeria, Egypt, Libya, Morocco, Sudan, Tunisia.
[1] Asia includes Near East countries
Source: United Nations World Population Prospects: The 1994 Revision

"Unless progress with agricultural yields remains very strong, the next century will experience sheer human misery that, on a numerical scale, will exceed the worst of everything that has come before."

Dr. Norman Borlaug
Nobel Prize Laureate
Importance of Irrigation

IMPORTANCE OF IRRIGATION

Crop Yields and Food Security__ According to the United Nations Food and Agriculture Organization, 30%-40% of worldwide food production comes from an estimated 260 million hectares of irrigated lands – only one-sixth of the world's farmland. Irrigated farms have 50% to 200 % higher yields for most crops. Water clearly plays a critical role in food production and this resource is central to major food security concerns, such as:

> Ever increasing human population;
> Concomitant increasing food needs;
> Finite natural resources;
> Degradation of natural resources.

Left: Sugar cane fields.

The impact of population growth on food supply and nutrition will be greatest in countries already challenged by poverty and inadequate nutrition. Even though food supplies have increased substantially over the past 30 years, more than 800 million people still do not have enough food to meet their basic nutritional needs.

For the world as a whole, agricultural production will slow from average annual growth of 2.3% during the 1970-1990 period to 1.8% during the 1990-2010 period. (Table 3.)

Table 3. Growth rates of gross agricultural production in percentage per annum

Region	Production			
	Total		Per capita	
	1970 -1990	1990 -2010	1970-1990	1990-2010
World	2.3	1.8	0.5	0.2
93 Developing Countries	3.3	2.6	1.1	0.8
Sub-Saharan Africa	1.9	3.0	-1.1	-0.2
Near East/North Africa	3.1	2.7	0.3	0.3
East Asia	4.1	2.7	2.4	1.5
South Asia	3.1	2.6	0.7	0.6
Latin America & Carribean	2.9	2.3	0.6	0.6
Developed Countries	1.4	0.7	0.6	0.2
Ex-CPE's	1.2	0.4	0.4	-0.1
Other Developed Countries	1.5	0.8	0.8	0.4

Source: FAO 1995 (a)

Slower Growth in Irrigation__ Over the past four decades, human civilization has grown more food and fiber by expanding its irrigated agricultural base. In the 1970s, this growth tracked at about 2.5% per year, and then began to fall to the current level of roughly 1% growth per year. That slow growth will apparently continue: some projections foresee 0.6% annual increases in irrigated agriculture from now to 2020.

Investment in new large-scale irrigation projects has fallen off over the past 20 years, and there is little change in that trend, with some exceptions such as the Toshka mega-project in Egypt. Higher project costs, lower lending levels, and low commodity prices are often cited as reasons for reduced investment in irrigation.

Rather than building new irrigation projects, some countries are modernizing their existing irrigation base to become more efficient and productive. Countries that develop vibrant irrigated agricultural segments will position their economies to capture new opportunities from these trends.

Slower growth in irrigated agriculture, compounded by the rising populations and demand for water by the domestic and industrial sectors, poses a major threat to world food production. To grow more food, the current base of irrigated land will become even more important. Currently, about 2.4 billion people depend on irrigated agriculture for food and jobs, and it is clear that many more will depend on this production system in the future.

Role of Water in Food Production__ Irrigated farmlands are inherently more productive than rainfed farming systems. Leveraging this productivity, according to FAO specialists, will be critical in bridging the gap between food production and food demand. Some key points that underline this reality follow:

> Crop production increased at a rate of 2.3% from 1970 to 1990. About two-thirds of that gain came from improved yields – mainly of irrigated wheat, rice, and maize. Only one-third of the food production gain came from farmland expansion. Irrigation increased both the yield per harvest and the number of harvests.

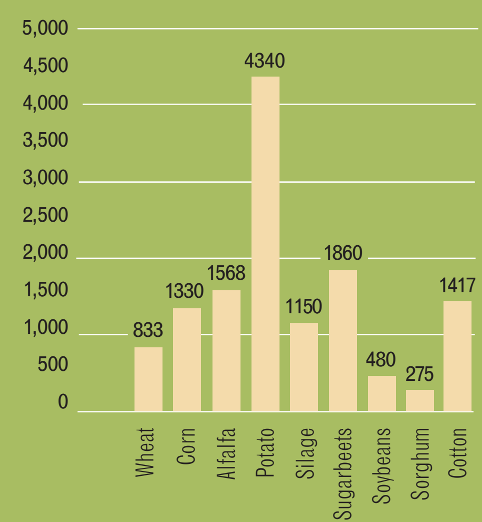
> One of the key advantages offered by modern irrigation is that it can ensure reliable production under erratic rainfall. Drought lowers crop yields, and also causes a plethora of other social and environmental costs from poor nutrition, natural resource damage, and risk-avoiding behavior of farmers. These costs of drought are also substantial, though they go frequently unmeasured.

> In general, farmers who irrigate are relatively more prosperous than their counterparts who rely on natural rain alone. Irrigation thus generates a suite of secondary economic activities. A study in Malaysia showed that each US $1.00 of value directly added by irrigation was accompanied by an additional US $ 0.80 of secondary economic value.

> Finally, mechanized move irrigation has the potential to transform subsistence farmers into profitable commercial farmers. A center pivot can thus offer to subsistence farmers an exit door from the cycle of eternal poverty in which so many of them are trapped.

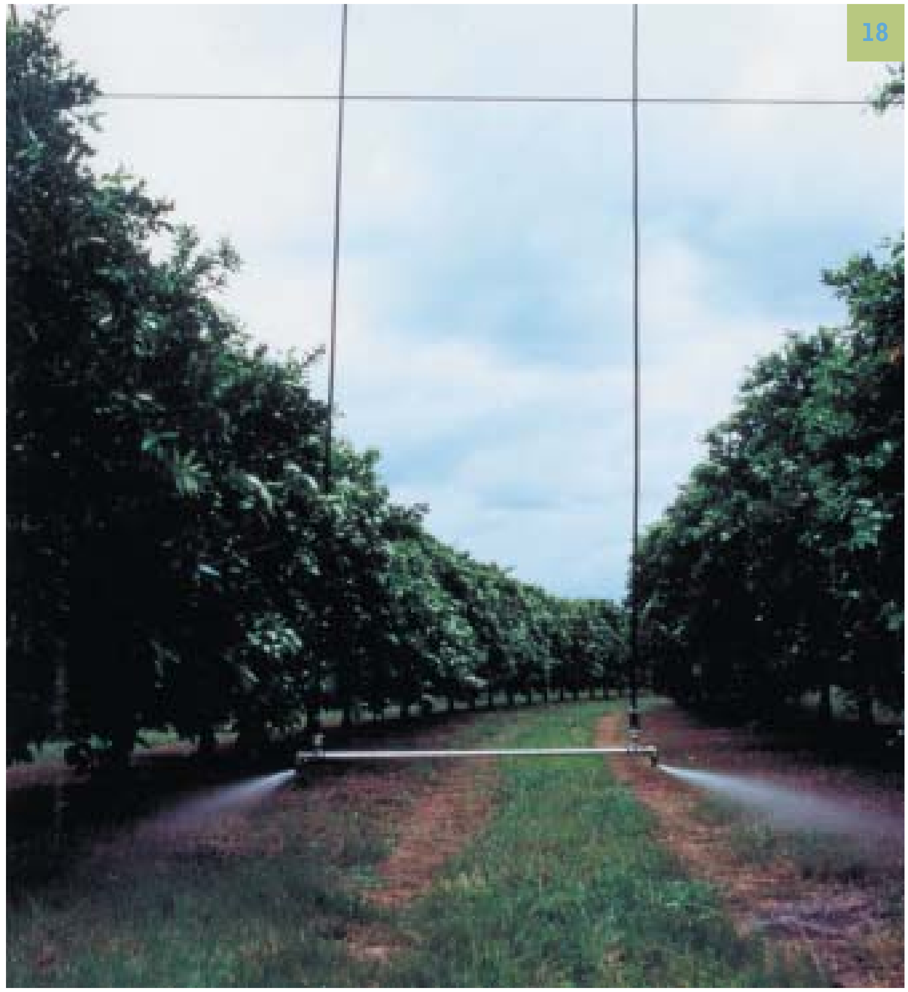
Below: These citrus orchards irrigated by Valley pivots in South Africa range in size from 15 to 45 hectares.

ADDED REVENUE FROM INCREASED YIELDS ($US/HA)



Irrigation increases yields compared to dryland farming.

Right: The pivot irrigating this citrus orchard is fitted with 'below the canopy' sprinklers which minimize evaporation and concentrate their spray directly over the crop root zone.



Water Availability and Scarcity__ In total, there is enough water to support a world population many times larger than the present one. Unfortunately, water is unevenly distributed across the surface of the earth. Many regions lack access to sufficient affordable fresh water. Competition among fresh water users in the agricultural, domestic, and industrial sectors is increasing as their water demands grow. (Table 4.)

Table 4. Distribution of water resources by continent

Continent	Area		Internal Renewable Water Resources (IRWR)					
						(m^3 per person per year)		
	1000 km^2	Percent of world total	Volume (km^3/year)	Percent of world total	Specific discharge (l/sec.km^2)	year 1990	year 2000	year 2010
Northern Africa*	8,259	6.2	85	0.2	0.3	593	475	394
Sub-Saharan Africa	21,766	16.2	3,906	8.9	5.7	7,988	5,980	4,579
Asia	27,675	20.6	10,886	24.8	12.5	3,489	2,975	2,608
Europe	4,877	3.6	2,321	5.3	15.1	4,651	4,542	4,523
Former USSR	22,276	16.6	4,413	10.0	6.3	15,304	14,918	14,483
South America	17,819	13.3	11,760	26.8	20.9	40,137	33,988	29,622
North & Central America	22,842	17.0	8,200	18.7	11.4	19,340	16,942	15,242
Australia	7,713	5.8	348	0.8	1.4	20,606	18,104	16,287
Oceania	823	0.6	2,040	4.6	78.6	213,836	178,493	151,707
World	**134,049**	**100.0**	**43,959**	**100.0**	**10.4**	**8,321**	**7,139**	**6,252**

* Northern Africa includes Algeria, Egypt, Libya, Morocco, Sudan, Tunisia.

Sources: Ayibotele, 1992; Gleick, 1993; WRI, 1994; FAO, 1995 (d); Shiklomanov, 1996; FAO, 1997

World Bank specialists estimate that 80 countries now have water shortages serious enough to threaten food production. Agriculture accounts for approximately 70% of human water usage today. However, the agricultural share of the water supply will decline as the water demand of households and industry increases. (Table 5.)

Table 5. Water use by continent

Continent	Water withdrawal					
	Agriculture%	Domestic%	Industries%	Total km^3/year	m^3/person per year	% of IRWR
Northern Africa*	87	7	6	94	658	111.0
Sub-Saharan Africa	83	12	5	56	114	1.4
Asia	86	6	8	1,531	491	14.1
Europe	33	13	54	359	719	15.5
Former USSR	65	7	28	358	1240	8.1
South America	59	19	23	133	454	1.1
North & Central America	49	9	42	697	1644	8.5
Australia & Oceania	34	64	2	23	870	1.0
World 1990	**69**	**8**	**23**	**3,251**	**615**	**7.4**
World Projection 2000	**63**	**10**	**27**	**5,190**	**843**	**11.8**

* Northern Africa includes Algeria, Egypt, Libya, Morocco, Sudan, Tunisia.
IRWR - Internal Renewable Water Resources
Sources: WRI, 1994; FAO, 1995; FAO, 1997

Hydrologists define as "water scarce" those countries where local water supplies average less than 1,000 m^3 per person per year. In 1990, about 275 million people lived in 33 countries where the internal renewable water supplies were less than1,000 m^3 per person per year. By 2010, more than 580 million people will live in 39 water scarce countries. In general, Africa and Asia are already showing signs of a worsening shortage in freshwater availability, and water quality is also declining globally.

Countries and regions where water resources are under particularly strong pressure are especially good candidates for increased food imports and irrigation modernization.

Below: Drop hoses on cotton.

Irrigation Potential__ Adoption of more efficient irrigation practices – along with improvements in water conveyance systems – will increase food security. Modern irrigation practices can improve productivity per unit of water used, while changes in conveyance systems will get more water to farms.

For example, the water distribution system in large parts of India and Pakistan was built on the idea of 'protective irrigation.' In order to reach as many farmers as possible, each farm received water only once every two weeks. While this system protected against crop failure and famine, such infrequent watering produces very low crop yields.

Additionally, this kind of irrigation practice encourages the overuse of water which can waterlog soils. Farmers who use traditional irrigation face the twin problems of soil salinity and waterlogging. In Pakistan, India, and China, to name just a few major examples, salinity has affected millions of hectares. As Sandra Postel points out in her book, *Pillar of Sand*, the ancient civilization of the "Fertile Crescent," located between the Tigris and Euphrates Rivers in what is today Iraq, met its demise because of the gradual salinization of the otherwise famously fertile soils. Both traditional flood irrigation methods and modern drip irrigation cause the gradual build-up of salts in the root zone of crops. Sprinkler irrigation methods, including mechanized move irrigation, can on the other hand be used to solve salinity problems, because they can leach the salts down below crop root zones.

Traditional irrigation systems face other problems as well, such as low efficiency in water distribution and use, unreliable water delivery, vandalism of structures, poor maintenance, and insufficient cost recovery. Steps taken to improve the productivity of such irrigation projects have generally fallen into three categories:

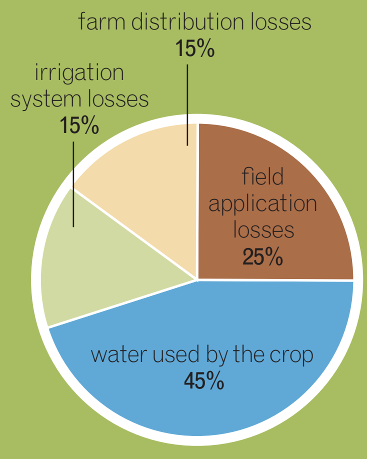
> The first concerns timeliness of water delivery. Predictable distribution ensures that water is available when crops need it most. This helps reduce stress-related yields and quality losses. Reliable supply also encourages farmers to make higher levels of investment in their cropping operations. Both improvements can increase the value of cropland output.

> Another way project managers try to enhance productivity is by storing unused water and applying it on newly irrigated land.

> A third kind of improvement involves the reduction of waterlogging and salinity problems. These problems decrease yields and degrade productive land. Eliminating over-application of water can result in production increases due to reduced salinity levels and improved aeration in crop root zones. Water saved through efficiency can go to other areas that are underserved.

A fourth trend should be added – conversion to mechanized irrigation. Traditional flood irrigation methods waste a great deal of water. Besides low water efficiency, over-watering also leads to low crop yields, especially as salts are brought up into the crop root zone. The precise water application afforded by mechanized move irrigation uses half as much water as flood, and prevents soil salinization. When water is applied uniformly across a field and in the exact amounts needed by the crop, the crop yields can be dramatically higher and the soil does not get water logged or overly salinized.

Average irrigation water losses



Source: UN FAO

Dark areas indicate where soil salinization is a major problem.

MODERNIZATION AND THE ENVIRONMENT

Fresh Water Conservation__ A recent World Bank report stated that unless current trends in water use are reversed, the world's water crisis will worsen. The world needs a healthy and growing food-producing sector. Irrigation will provide enormous value in terms of food security. With growing concerns over the world's fresh water supply, center pivot systems provide a sensible alternative to inefficient forms of water application, such as surface flood irrigation. Water use in irrigation could be lowered dramatically with no loss in food production.

Center pivot systems greatly reduce excess water use by applying precise amounts of water to crops at the right times and in the right quantities. Modern mechanized equipment is extremely water efficient. Specialists define irrigation system efficiency as the ratio between the water applied by an irrigation system and the water used by the plants on that field.

Traditionally, surface irrigation methods achieve efficiencies ranging from 40% to 70%, if field runoff is collected in holding ponds for reuse. In much of Asia, surface irrigation efficiency ranges from 25% to 40%. Losses of water in the distribution system and in farm fields account for much of the loss.

The irrigation efficiencies achieved by center pivot and linear move systems range from 75% to 98% depending on sprinkler package design, irrigation scheduling, and other agronomic practices, such as LEPA (Low Energy Precision Application), that can optimize the water efficiency of mechanical move irrigation technology. Exact quantities of water are delivered to crops, and with proper design, runoff and evaporation losses are nearly eliminated. Mechanical move irrigation technology ranks side by side with drip irrigation as the most water-efficient forms of irrigation available today.

Another problem with surface irrigation is the lack of uniform application. Frequently, water must be over-applied on one side of a field so it can flow to all parts of a field. This leads to waterlogging, lower yield and quality, and soil degradation. Uneven water distribution in surface irrigation is a key cause of reduced crop quality and yields.

A center pivot or linear system can apply water at 88% to 95% uniformity, compared to 40% to 70% uniformity with surface irrigation.

Far left: Center Pivots are not limited to irrigating flatland.
Left: Desert agriculture has flourished through the widespread use of center pivot technology.

The world has approximately 260 million hectares of irrigated land. If just 1% of this land was converted from traditional irrigation methods to precision methods, more than 7 billion kiloliters of water could be conserved annually. These savings would make a major contribution in solving water shortages around the world. Precise, uniform application not only conserves water, it also increases crop yields, quality, and revenue. Modern irrigation methods can help the world grow more food with less water.

Water Quality__ Another major issue facing surface irrigation is water contamination from chemicals. Fertilizers, pesticides and other pollutants can leach into groundwater and pollute streams, lakes, and rivers when chemical-laden irrigation water is over-applied and flows from farm fields into other waters.

Mechanized irrigation enhances environmental safety. By applying only as much water as the soil can absorb, runoff is eliminated or reduced significantly.

Since tillage is not needed to prepare cropland to convey water in furrows, more protective crop residue cover can be left on fields. Most water pollution is caused by soil sediment. Increased crop residue helps keep soil in place to reduce erosion. Coincidentally, chemical contaminants are often carried into waterways on soil particles. Controlling soil erosion thus also contributes to reduced chemical contamination.

Using mechanized irrigation to apply crop inputs permits more precise control of irrigation rates and timing, which increases the effectiveness of crop chemicals and fertilizer. Potential treatment needs may be reduced. Also, more effective irrigation improves plant health. Lush crops can shade weeds and better withstand insect pressure, making some treatments unnecessary. In similar fashion, the equipment can be used to apply growth regulators and harvest aid products on crops such as cotton.

Research has also shown that center pivot irrigation equipment can draw on groundwater that is contaminated by fertilizer and filter that water through the crop root zone. Cleaner water is the result.

In some areas, wastewater treatment is a major challenge. Center pivots and linear move systems can apply partially treated wastewater onto cropland. Again, crop roots filter the nutrients and clean the water. This results in major savings by avoiding added costs for additional capacity in sewage systems.

Protecting Soil Resources__ Salinity is often a problem in surface irrigation. When soils become waterlogged, salts accumulate in the root zone of plants and on the surface of fields. Up to 15 million hectares have incurred lower crop yields from salinization. Yields can be reduced up to 30%. In extreme cases, the land may be removed from cultivation.

Protecting current irrigated land from further salinization will help reduce productivity losses. Reclaiming lands already affected by salinity also should be pursued to protect the irrigated land base. Modern irrigation technology can help in both situations.

Both leading modern irrigation technologies – drip systems and mechanical move systems – apply less water than surface irrigation, which eases problems associated with waterlogged soils and poor drainage. Also, mechanical move irrigation systems can apply water to flush salt deposits below the crop root zone. By carefully controlling this leaching effect, salts can be flushed from soils while avoiding waterlogging.

Research and experience with managing salinity by Valmont Irrigation shows great promise in solving this problem. Valmont has studied this problem in the southwestern United States, where salinization has become a major concern.

The test area is characterized by hot, dry conditions. Water comes from a saline river source. The flat field had been watered with surface irrigation and was converted to linear irrigation. This equipment was used to apply light, frequent waterings. Saline burn to the crop was avoided, water requirements were met, and yield performance was very promising. Four crops were to be planted in the field over a three-year period, increasing the number of harvested crops.

Salinity is a major challenge for irrigated agriculture. It can damage the land, reduce yields and interfere in the growth of food production. Mechanized irrigation can help solve these problems.

Reduced runoff from irrigation can also help protect the productive capacity of soils. Water soaks into the soil rather than running off the field, preventing soil erosion. With less tillage needed under center pivots, less soil will blow away in the wind. Healthy soils are critical to farmland productivity. Mechanized irrigation helps protect them.

There are many ways that mechanized irrigation can contribute to enhanced environmental quality – using less water, reducing runoff and potential chemical contamination, and solving soil salinization problems.

Below: Salt build-up in surface irrigated onions at salinity test site. Most irrigation techniques cause salts to build up in soils. Center pivots can both remediate and prevent soils salinization.
Above right: Corn is one of the crops most commonly irrigated by center pivots because of its responsiveness to irrigation.

ABOUT VALMONT

Irrigation Leader__ Valmont Industries, Inc., is the world's largest manufacturer and distributor of mechanized irrigation systems, having created the industry in 1954. Valmont's Valley brand equipment, and the international Valley dealer organization are today known the world over as the most trusted and innovative source of irrigation equipment and service.

Valmont has established valuable relationships with other world-class companies involved in agriculture and public infrastructure. The company has gained vast knowledge from its associations with farm equipment companies, seed, chemical and biotechnology manufacturers, hydrology consulting organizations, public works advisory firms, and the agricultural research community.

Valmont has equipment operating in virtually every part of the world. Valmont's experiences and partnerships form a unique base of knowledge that the company puts to work for its customers.

Ultimately, Valmont is the most successful company in mechanized irrigation because it has the greatest commitment to the success of its customers – supplying reliable, long-lasting products, the most advanced research and innovation, and outstanding field support and services.

International Sales__ Valmont began developing overseas markets in the early 1970s. By 1979, Valmont began to capitalize on these opportunities as governments sought to modernize less efficient irrigation systems and develop arid regions. Over time, Valley products were widely accepted and praised by growers in Europe, the Middle East, Africa, Australia, the People's Republic of China, and Latin America.

Other Businesses__ Over the years, Valmont's success fostered the growth of additional business lines. Pipe and tubing were added out of necessity. As the company's pipe markets grew, the product was extended into lighting poles.

Today, Valmont's Poles Division is the world's leader in supplying engineered metal structures, including: communication towers and components for the cellular phone industry; lighting and traffic signal structures for public and private markets; utility poles for energy transmission, and electrical sub-station structures. Valmont also makes tubular steel products, fasteners, and other small items. Valmont's Coatings division is the largest galvanizer in the United States.

Figure 1:

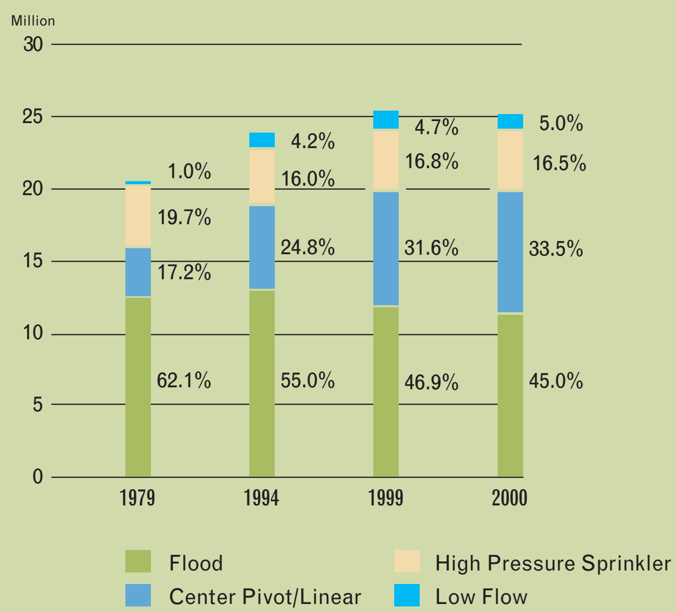
IRRIGATED AREA, BY REGION, 1961 TO 2000 THOUSAND HECTARES
(2)

REGION	1961	1965	1970	1975	1980	1985	1990	1995	2000
World	138,989	149,976	167,803	188,225	209,716	225,138	244,305	261,380	271,689
Africa	7,410	7,795	8,483	9,010	9,491	10,331	11,235	12,380	12,680
Asia	90,166	97,093	109,666	121,565	132,377	141,922	155,009	180,461	190,083
Europe	8,324	9,225	10,355	12,296	13,979	15,479	16,744	25,208	24,508
North & Central America	17,949	19,525	20,938	22,831	27,593	27,464	28,905	30,657	31,406
Oceania	1,079	1,368	1,588	1,620	1,684	1,957	2,113	2,688	2,674
South America	4,661	5,070	5,673	6,403	7,392	8,296	9,499	9,986	10,338
USSR	9,400	9,900	11,100	14,500	17,200	19,689	20,800	(1)	(1)
Total	**138,989**	**149,976**	**167,803**	**188,225**	**209,716**	**225,138**	**244,305**	**261,380**	**271,689**

Notes:
1. After 1990, all irrigated area in the former USSR is split among Europe and Asia.
2. Data from 1961 to 1995 are from The World's Water 2002-2003.
3. The Data for 2000 is from UN FAO, Web site at www.fao.org.
Reference: Peter Gleick, The World's Water 2002-2003

Figure 2:

TOTAL IRRIGATED HECTARES IN THE USA



1979 data: *USDA statistics*
1994 - 2000 data: *Irrigation Journal Survey*

Over the years, the percentage of flood irrigated land has decreased, while the use of center pivots and linears has had the most significant increase of these primary methods of irrigation in the US.

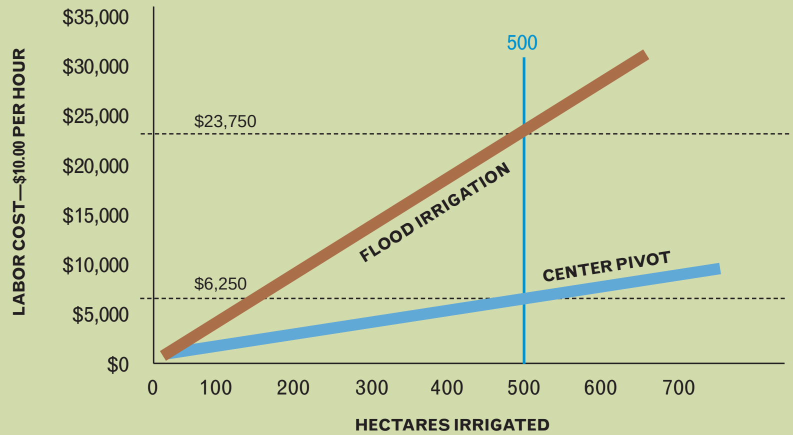
Figure 3:

	HECTARES (millions)			
	1979	1994	1999	2000
Low Flow	0.2	1.0	1.2	1.3
High Pressure Sprinkler	4.0	3.8	4.3	4.2
Center Pivot/Linear	3.5	5.9	8.1	8.5
Flood	12.6	13.1	12.0	11.5
Total Hectares	20.3	23.8	25.6	25.5

Figure 4:

LABOR COST PER YEAR/PER HECTARE

As the size of the irrigated field increases, the labor cost using flood irrigation also dramatically increases. The labor cost of center pivot systems, on the other hand, increases only slightly with field size, since one person can run multiple pivots, covering thousands of hectares.



500 hectares = approximately 10 center pivots

The data in Figure 4 is based on a University of Nebraska study, "Comparison of Irrigation Distribution Systems."

Figure 5:

Total Water Usage	1 Year
Flood	449.7 million liters
Pivots	204.5 million liters
Savings	**245.2 million liters**

By irrigating with a center pivot, over a 20 year period your water savings can amount to 4.9 billion liters.

FLOOD

$4{,}164 \frac{\text{liters}}{\text{minute}} \times 60 \frac{\text{minutes}}{\text{hour}} \times 1800$ Hours (75 Days) = 449.7 million liters

CENTER PIVOT

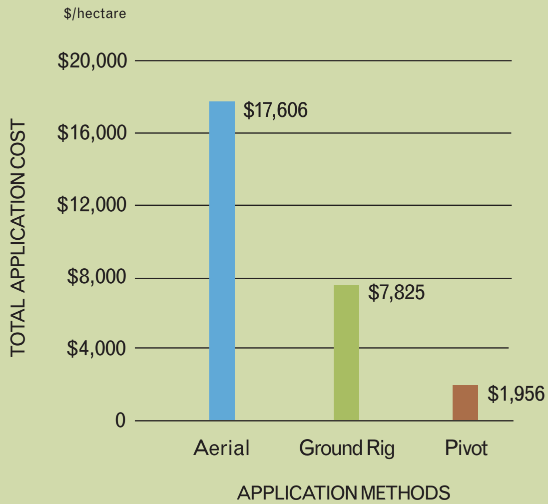
$2{,}840 \frac{\text{liters}}{\text{minute}} \times 60 \frac{\text{minutes}}{\text{hour}} \times 1200$ Hours (50 Days) = 204.5 million liters

These estimates take into account the typical practices of flood irrigating for 75 days per season, while only 50 days of irrigation per season are typical with center pivots.

Data in Figure 5 is based on findings from a study conducted by Servi-Tech Incorporated, the largest crop consulting organization in the United States.

Figure 6:

CHEMICAL APPLICATION COSTS (Based on 53.5 hectares and 12 applications)



Using aerial or ground rig methods to apply chemicals can be extremely expensive. With a center pivot, you can apply chemicals directly through the pivot and save a substantial amount of money.

Figure 7:

Pumping Costs		Electricity		Diesel Fuel
Flood	$	13,659.55	$	13,570.57
Pivots	$	6,405.00	$	6,363.28
Savings	**$**	**7,254.55**	**$**	**7,207.29**

(Totals calculated over a one year period)

When using a center pivot, over a 20 year period, you can save over $144,000 in both electricity and diesel fuel costs.

ELECTRICITY COST - FLOOD

$$\frac{\text{(1,800 hours/year) x (95.4 kilowatts*) x (\$.26/liter)}}{\text{.88 kilowatts}} = \$\ 13,659.55$$

ELECTRICITY COST - PIVOT

$$\frac{\text{(1,200 hours/year) x (67.1 kilowatts**) x (\$.07/kilowatts-HR)}}{\text{.88 kilowatts}} = \$\ 6,405.00$$

DIESEL FUEL COST - FLOOD

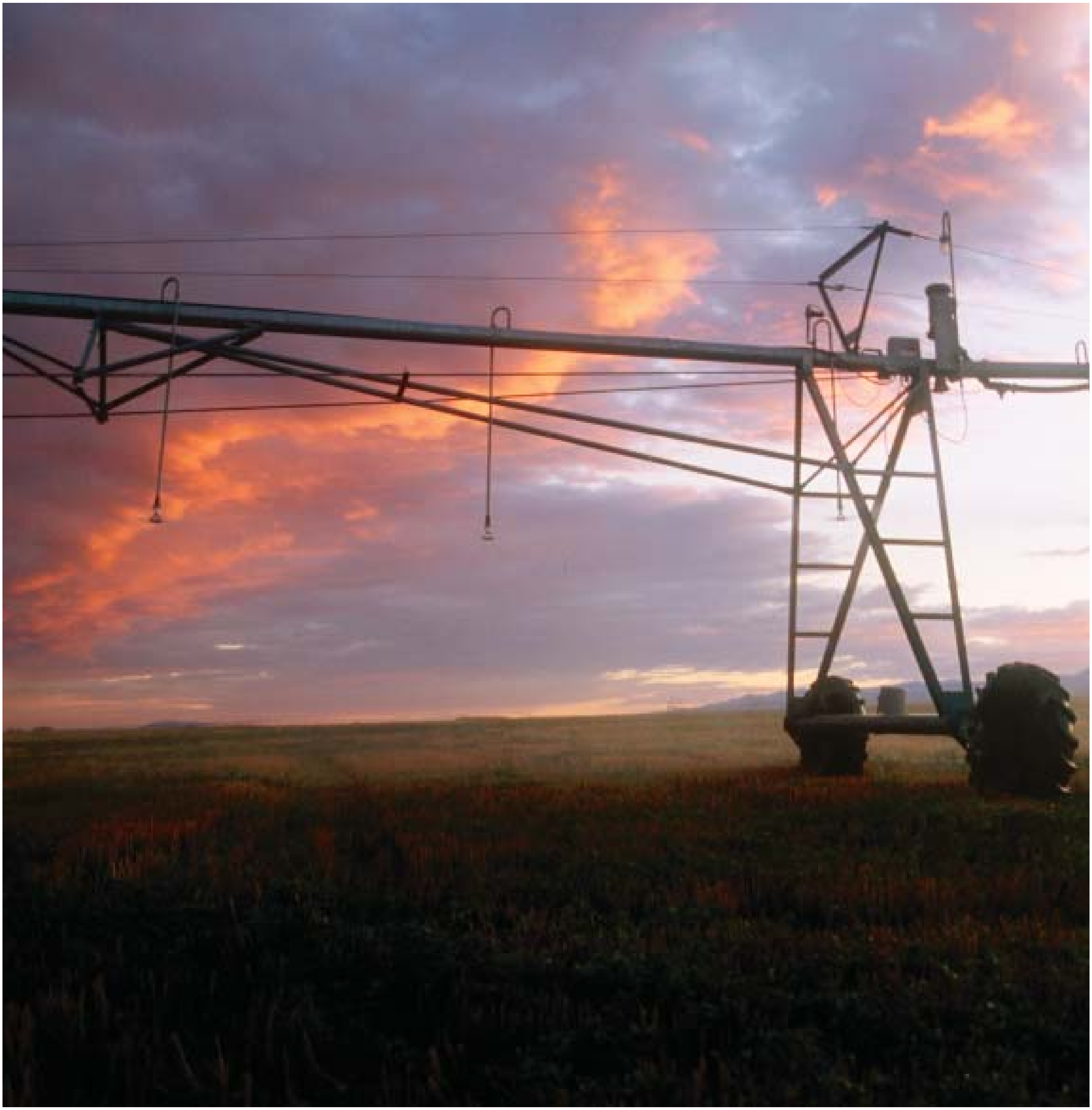
$$\frac{\text{(1,800 hours/year) x (95.4 kilowatts) x (\$.26/liter)}}{\text{3.29 kilowatts-HR/liter}} = \$\ 13,570.57$$

DIESEL FUEL COST - PIVOT

$$\frac{\text{(1,200 hours/year) x (67.1 kilowatts) x (\$.26/liter)}}{\text{3.29 kilowatts-HR/liter}} = \$\ 6,363.28$$

**95.4 kilowatts based on 69.4 liters/second, 91.4 meters of lift, 1.38 bars discharge pressure, and 75% pump efficiency.*
***67.1 kilowatts based on 47.3 liters/second, 91.4 meters of lift, 1.72 bars discharge pressure, and 75% pump efficiency.*

Pumping cost and chemigation cost analysis are based on findings from a study conducted by Servi-Tech Incorporated, the largest crop consulting organization in the United States.

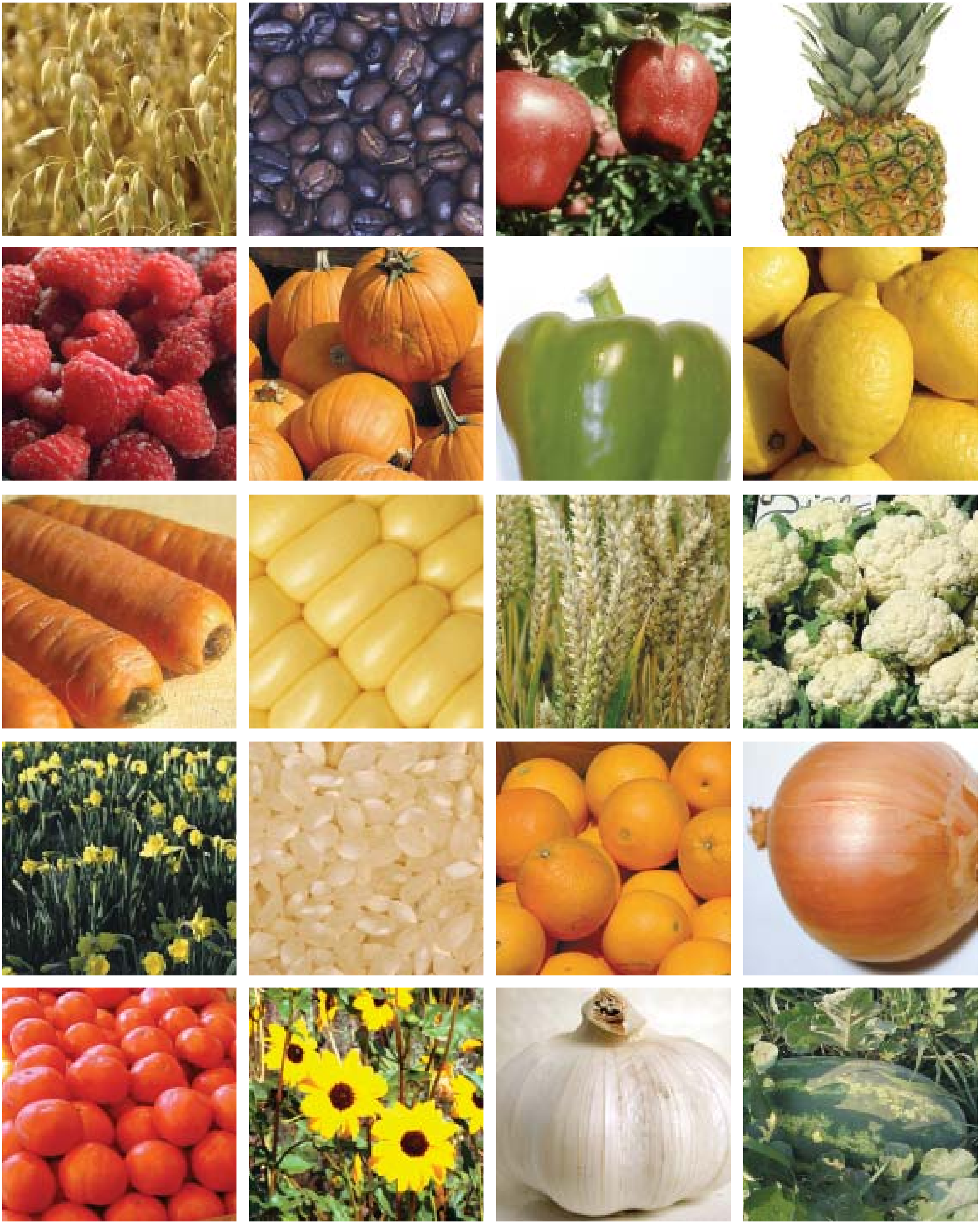


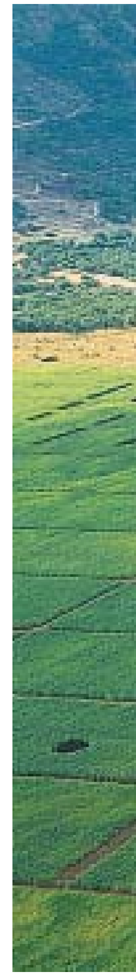
CROP VERSATILITY OF PIVOTS

Any plant that grows under rain can grow under a pivot, as long as the crop height does not exceed 5 m.

Abaca (Manila Hemp)
Agave Fibres
Almonds
Anise, Badian, Fennel
Apples
Apricots
Areca Nuts (Betel)
Artichokes
Asparagus
Avocados
Bambara Beans
Barley
Beans, Dry
Beans, Green
Berries
Blueberries
Broad Beans, Dry
Broad Beans, Green
Buckwheat
Cabbages
Canary Seed
Cantaloupes and other Melons
Carobs
Carrots
Cashewapple
Cassava
Castor Beans
Cauliflower
Cereals
Cherries
Chick-Peas
Chicory Roots
Chilies and Peppers, Green
Citrus Fruit
Cloves, Whole and Stems
Coarse Grain
Coffee, Green
Coir
Cow Peas, Dry
Cranberries
Cucumbers and Gherkins
Currants
Eggplants
Fibre Crops
Figs
Flax Fibre and Tow
Flowers
Fonio
Fruit, Fresh
Fruit Tropical, Fresh
Garlic
Ginger
Gooseberries
Grapefruit and Pomelo
Green Corn (Maize)
Groundnuts in Shell
Hazelnuts (Filberts)
Hemp Fibre and Tow
Hempseed
Hops
Jute
Jute-Like fibres
Kapok Fibre
Kapokseed in Shell
Karite Nuts (Sheanuts)
Kolanuts
Lemons and Limes
Lentils
Lettuce
Linseed
Lupins
Maize
Mate
Melonseed
Millet
Mixed Grain
Mustard Seed
Nutmeg, Mace, Cardamons
Nuts
Oats
Oilseeds
Okra
Olives
Onions and Shallots, Green
Onions, Dry
Oranges
Peaches and Nectarines
Pears
Peas, Dry
Peas, Green
Peppermint
Pepper,White/Long/Black
Persimmons
Pigeon Peas
Pimento, Allspice
Pineapples
Plantains
Plums
Pop Corn
Poppy Seed
Potatoes
Pulses
Pumpkins, Squash, Gourds
Pyrethrum, Dried Flowers
Quinces
Quinoa
Ramie
Rapeseed
Raspberries
Rice, Paddy
Roots and Tubers
Rye
Safflower Seed
Seed Cotton
Sesame Seed
Sisal
Sorghum
Sour Cherries
Soybeans
Spices
Spinach
Stone Fruit, Fresh
String Beans
Sugar Beets
Sugar Cane
Sugar Crops
Sunflower Seed
Sweet Potatoes
Tangerine, Manderin, Clementine, Satsma
Taro (Coco Yam)
Tea
Tobacco Leaves
Tomatoes
Vegetables Fresh
Vetches
Watermelons
Wheat
Yams
Yautia (Coco Yam)

Above Right: ***Barley, Coffee, Apples, Pineapple, Raspberries, Pumpkins, Green Pepper, Lemons, Carrots, Corn, Wheat, Cauliflower, Daffodils, Rice, Oranges, Onion, Tomatoes, Sunflowers, Garlic, Watermelon***





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