Chapter 5 Selecting an Irrigation Method

Contents:

Tables

Chapter 5 Selecting an Irrigation Method

652.0500 General

Irrigation application method and system selection should result in optimum use of available water. The selection should be based on a full awareness of management considerations, such as water source and cost, water quantity and quality, irrigation effects on the environment, energy availability and cost, farm equipment, product marketability, and capital for irrigation system installation, operation, and maintenance. The purpose of this chapter is to provide necessary planning considerations for selecting an irrigation method and system. Most widely used irrigation methods and systems with their adaptability and limitations are described. Also see National Engineering Handbook (NEH), part 623 (section 15), chapters 3, 4, 5, 6, 7, 8, 9, and 11.

In some areas, operators are accustomed to a particular irrigation method and system of applying water. They continue to install and use this common system even though another system may be more suitable, apply water more efficiently with better distribution uniformity, be more economical to install and operate, and have fewer negative impacts on ground and surface water.

The consultant and irrigation decisionmaker should compare applicable methods and systems on common grounds. These can include:

- Gross irrigation water needs
- Energy requirements
- Effects on quantity and quality of ground water and downstream surface water
- Installation and annual operating costs
- Labor skills needed

Generally more than one irrigation method and system can be installed and efficiently operated on a specific site. The owner's or operator's desire, rather than economics and water application uniformity, may be key to the selection. To get acceptable irrigation efficiencies (minimize losses), management skills required of the operator and flexibility of available labor must be considered. Local regulations may provide the motivation to select and manage a specific irrigation system that would provide the least negative effect on ground and surface water. Whatever basis is used for the decision, the consultant and owner or operator both need to be aware of the applicability, capability, and limitations of all irrigation methods and systems that could be used on a specific site.

Political, legal, and regulatory issues are of primary importance. Included are such issues as land reform, water rights, containment of runoff and drainage water, taxation, financial incentives from governments, zoning and site application, and construction permits. These issues must be fully understood at the beginning of the selection process.

The Natural Resources Conservation Service (NRCS) Field Office Technical Guide, section V, displays the conservation effects of irrigation methods and systems and their related components. These should be referenced during the planning and design process. They will provide insight as to the effects of surface irrigation on ground and surface water quantity and quality, and on wildlife.

652.0501 Methods and systems to apply irrigation water

The four basic irrigation methods, along with the many systems to apply irrigation water, include: surface, sprinkle, micro, and subirrigation:

Surface—Water is applied by gravity across the soil surface by flooding or small channels (i.e., basins, borders, paddies, furrows, rills, corrugations)

Sprinkle—Water is applied at the point of use by a system of nozzles (impact and gear driven sprinkler or spray heads) with water delivered to the sprinkler heads by surface and buried pipelines, or by both. Sprinkler irrigation laterals are classed as fixed set, periodic move, or continuous or self move. Sprinkler irrigation systems include solid set, handmove laterals, sideroll (wheel) laterals, center pivot, linear move (lateral move), and stationary and traveling gun types. Low Energy Precision Application (LEPA) and Low Pressure In Canopy (LPIC) systems are included with sprinkler systems because they use center pivots and linear move irrigation systems.

Micro—Water is applied to the point of use through low pressure, low volume discharge devices (i.e., drip emitters, line source emitters, micro spray and sprinkler heads, bubblers) supplied by small diameter surface or buried pipelines.

Subirrigation—Water is made available to the crop root system by upward capillary flow through the soil profile from a controlled water table.

Each irrigation method and irrigation system has specific site applicability, capability, and limitations. Broad factors that should be considered are:

- Crops to be grown
- Topography or physical site conditions
- Water supply
- Climate
- Energy available
- Chemigation
- Operation and management skills
- Environmental concerns
- Soils
- Farming equipment
- Costs

652.0502 Site conditions

Table 5–1 displays the site and other local conditions that must be considered in selecting an irrigation method and system. Other factors to consider include:

Farm, land, and field—Field size(s) and shape, obstructions, topography, flood hazard, water table, and access for operation and maintenance.

Energy and pumping plant—Type, availability, reliability, parts and service availability, and pumping efficiency.

Environmental effects—On quantity and quality of surface and ground water for water removal and for return flows, on local air quality, on local and regional wildlife and fish.

Local laws—Laws regarding tailwater runoff reuse, reuse pits, and quality of tailwater (runoff).

Type and amount of effluent—Animal, municipal, and industrial waste.

Water rights, allocations, and priority.

Availability of funds for improvements.

Sociological factors (i.e., grandpa and dad did it that way)—Available technical ability and language skills of laborers.

Time and skill level of management personnel.

Table 5–1 Site conditions to consider in selecting an irrigation method and system

Crop	Soil	Water	Climate
Crops grown & rotation	AWC	Quality	Wind
Water requirement	Infiltration rate	salts, toxic elements	Rainfall
Height	Depth	sediment	Frost conditions
Cultural practices	to water table	organic materials	Humidity
Pests	to impervious layer	fish, aquatic creatures	Temperature extremes
Tolerance to spray	Drainage	Quantity	Rainfall frequency
Toxicity limitations	surface	Reliability	Evaporation from:
Allowable MAD level	subsurface	Source	plant leaves and stems
Climate Control	Condition	stream	soil surface
frost protection	Uniformity	reservoir	Solar radiation
cooling	Stoniness	well	
Diseases & Control	Slope (s)	delivery point	
Crop quality	Surface texture	Delivery schedule	
Planned yield	Profile textures	frequency	
	Structure	duration	
	Fertility	rate	
	Temporal properties		

652.0503 Selection of irrigation method and system

With the current demand for other uses of high quality water, the irrigation decisionmaker must provide good irrigation water management; including maximizing beneficial water use, providing good distribution uniformity, minimizing water losses, and using an appropriate irrigation scheduling method. For example, it has been demonstrated that micro systems can be economically used on high value annual and perennial crops. However, high quality water from a suitably treated or filtered source is required to minimize emitter plugging, especially when using buried laterals having line-source emitters. Any properly designed, installed, and managed irrigation method and system, that is suitable to the site, has the potential to apply the proper amount of water uniformly across the field. However, one or more systems can be less costly and easier to manage.

Local regulatory standards and criteria for irrigation efficiency, maximum water duty, or maximum water losses may strongly recommend the selection of one or two specific irrigation systems so that water is applied without excessive negative impacts on local water quantity and quality. The fact that the best planned, designed, and installed system can still be grossly mismanaged must also be recognized. Availability of irrigation equipment replacement parts, repair service, skilled labor for system operation, and irrigation water availability and timing must be considered. Minimizing total annual operating energy requirements should be a basic part of the decisionmaking process.

Two irrigation methods (i.e., sprinkle and surface) and systems for the same field can be efficiently used with different crops and even a single crop for one season. For example, with an annual crop such as corn on high intake soils, early season shallow irrigations can be provided to the shallow rooted corn plants by handmove or sideroll (wheel) sprinkler laterals. After the corn gets too tall for the moving of laterals and the water infiltration rate is slowed by tillage equipment compaction, furrow irrigation can then be used for the remainder of the season. Compared to a full irrigation season using furrows, less water is applied and fewer plant nutrients and pesticides are lost to deep percolation below the root zone. In cranberry bogs, sprinklers can be used for irrigation, frost control, and chemical application, or bogs can be flooded for irrigation and frost control. Lettuce, carrots, onions, and other such crops can be germinated with portable fixed set sprinkler laterals with furrows used to apply water the balance of the growing season.

Where ample water is available during the early part of the growing season, but becomes deficient during the peak water use period, a surface flood system (i.e. borders) can be used in the spring and a sprinkler system used during peak water use. Several benefits can be realized with both irrigation methods:

- Reduced energy use compared to pumping the full flow for the full season
- Maximized water use efficiency during the peak water use period

This scenario works well where surface water with gravity flow is available to the field and both a good surface flood system and sprinkler system are available or can be economically installed.

Sprinkler irrigation systems are adaptable for use on most crops and on nearly all irrigable soils. Particular care is needed in the design and operation of a sprinkler system with low application rates (0.15 to .25 in/hr) and on soils (generally fine textured) with low infiltration rates. Principal concerns with low application rates are time of set, increased system cost, acceptable distribution uniformity, wind drift, evaporation, and system operational requirements.

For example, with an application rate of 0.15 inch per hour, *time of set* would have to be nearly 30 hours to apply a net irrigation application of 3 inches. It is recommended that sprinkler systems apply water at a rate greater than 0.15 inch per hour for improved wind resistance. In areas of high temperature, wind, or both, minimum application rate and volume should be higher because of potential losses from evaporation and wind drift. For frost control, where evaporation and wind drift potential are low, an application rate of 0.10 to 0.15 inch per hour is common. See NEH, Part 623 (Section 15), Chapter 11, Sprinkle Irrigation.

Most irrigation application methods and systems can be automated to some degree. More easily automated are micro systems, center pivot sprinkler systems, solid set sprinkler systems, level furrow and basin systems, graded border systems, subsurface systems, and graded furrow systems using automated ditch turnouts, cutback, cablegation, and surge techniques.

Table 5–2 displays estimated typical life and annual maintenance for irrigation system components. Also, see chapter 11 of this guide for additional information on developing and comparing typical capital and operating costs for selected irrigation systems.

Table 5–2 Typical life and annual maintenance cost percentage for irrigation system components

System and components	Life (yr)	Annual maint. (% of cost)	System and components	Life (yr)	Annual maint. (% of cost)
Sprinkler systems	10 - 15	2 - 6	**Surface & subsurface systems**	15	5
Handmove	15 +	2			
Side or wheel roll	15 +	2	**Related components**		
End tow	10 +	3	Pipelines		
Side move w/drag lines	15 +	4	buried thermoplastic	25 +	1
Stationary gun type	15 +	2	buried steel	25	1
Center pivot—standard	15 +	5	surface aluminum	20 +	2
Linear move	15 +	6	surface thermoplastic	5 +	4
Cable tow	10 +	6	buried nonreinforced concrete	25 +	1
Hose pull	15+	6	buried galv. steel	25 +	1
Traveling gun type	10 +	6	buried corrugated metal	25 +	1
Fixed or solid set			buried reinforced PMP	25 +	1
permanent	20 +	1	gated pipe, rigid, surface	10 +	2
portable	15 +	2	surge valves	10 +	6
Sprinkler gear driven, impact & spray heads	5 - 10	6			
			Pumps		
Valves	10 - 25	3	pump only	15 +	3
			w/electric motors	10 +	3
Micro systems 1/	1 - 20	2 - 10	w/internal combustion engine	10 +	6
Drip	5 - 10	3			
Spray	5 - 10	3	Wells	25 +	1
Bubbler	15 +	2	Linings		
Semi-rigid, buried	10 - 20	2	nonreinforced concrete	15 +	5
Semi-rigid, surface	10	2	flexible membrane	10	5
Flexible, thin wall, buried	10	2	reinforced concrete	20 +	1
Flexible, thin wall, surface	1 - 5	10			
Emitters & heads	5 - 10	6	Land grading, leveling	2/	
Filters, injectors, valves	10 +	7	Reservoirs	3/	

1/ With no disturbance from tillage and harvest equipment.
2/ Indefinite with adequate maintenance.
3/ Indefinite with adequate maintenance of structures, watershed.

652.0504 Adaptability and limitations of irrigation methods and systems

Tables 5–3 through 5–7 display factors that affect the adaptation and operation of various irrigation methods and systems. In these tables, the **+** indicates positive effects or provides good reasons for preference of selection, the **–** indicates negative effects or provides possible reasons for not choosing this alternative (another method or system should be considered), and the **0** indicates neutral effect or should provide no influence on selection.

Tables 5–8 and 5–9 give recommended slope limitations for surface and sprinkler irrigation systems.

Table 5–3 Factors affecting the selection of surface irrigation systems

Item	Level [1]: border basin	Level [1]: furrow	Graded: border reg	Graded: furrow mod [2]	Graded: furrow	Graded: corrug	Contour: levee	Contour: furrow	Contour: ditch
Crop									
Field—close growing	0	0	0	–	–	0	0	–	0
Field—row	0	0	–	0	+	–	0	–	
Vegetable—fresh	–	0	–	0	+	–	–	0	–
Vegetable—seed	–	0	–	0	+	–	–	0	–
Orchards, berries, grapes	0	0	0	0	0	–	–	0	–
Alfalfa hay	0	–	0	–	–	0	0	–	0
Corn	–	0	–	0	+	–	–	0	–
Cotton	–	0	–	0	+	–	–	0	–
Potatoes, sugar beets	–	0	–	0	+	–	–	0	–
Land & soil									
Low AWC	0	0	0	0	0	0	0	0	–
Low infiltration rate	+	+	0	0	0	0	+	0	0
Mod. infiltration rate	0	0	0	0	0	0	0	0	0
High infiltration rate	–	–	–	–	+	–	–	–	–
Variable infiltration rate	–	–	–	–	0	–	–	–	–
High salinity or sodicity	+	+	0	–	+	–	–	–	0
Highly erodible	–	–	–	–	–	–	–	–	–
Undulating topography	–	–	–	–	–	–	–	–	–
Steep topography	–	–	–	–	–	–	–	–	–
Odd shaped fields	+	+	–	–	–	–	0	0	0
Obstructions [3]	–	–	–	–	–	–	–	–	–
Stony, cobbly	–	–	–	–	–	–	–	–	–
Water supply									
Low cont. flow rate	–	–	–	0	0	0	–	0	0
High intermit. flow rate	+	+	+	–	–	–	–	–	0
High salinity	+	+	0	–	0	0	0	–	0
High sediment content	0	0	0	0	0	0	0	0	0
Delivery schedule									
continuous	–	–	0	0	0	0	0	0	0
rotation	0	0	0	0	0	0	0	0	0
arranged, flexible	0	0	0	0	0	0	0	0	0
demand	+	+	0	0	0	0	0	0	0
Climate									
Humid & subhumid	–	–	–	–	–	–	–	–	–
Arid & semiarid	0	0	0	0	0	0	0	0	0
Windy	0	0	0	0	0	0	0	0	0
High temp – humid	0	0	0	0	0	0	0	0	0
High temp – arid	0	0	0	0	0	0	0	0	0
Social/Institutional									
Easy to manage	0	+	–	–	–	–	–	–	–
Automation potential	+	+	0	–	+	–	0	0	–

1/ When used in humid and subhumid areas, protected outlets may be needed for surface runoff due to precipitation.
2/ Modified furrow irrigation includes cutback, surge, cablegation, and tailwater reuse.
3/ Obstructions may include roads, buildings, and rock piles.

Table 5–4 Factors affecting the selection of periodic move, fixed, or solid set sprinkler irrigation systems

Item	- - - - Periodic move - - - -			- - - Solid set or fixed - - -		
	sideroll	hand	gun	perm	port	gun
Crop						
Field—close growing	0	0	0	0	0	0
Field—row	0	0	0	–	0	–
Vegetable—fresh	0	0	0	0	0	0
Vegetable—seed	–	–	–	–	–	–
Orchards, berries, grapes	–	0	–	+	+	–
Alfalfa hay	0	0	0	–	–	–
Corn	–	–	0	–	–	0
Cotton	–	–	–	–	–	–
Potatoes, sugar beets	0	0	0	–	0	–
Land & soil						
Low AWC	0	0	0	+	+	+
Low infiltration rate	0	0	–	0	0	–
Mod. infiltration rate	0	0	0	0	0	0
High infiltration rate	0	0	0	+	+	+
Variable infiltration rate	+	+	+	+	+	+
High salinity or sodicity	–	–	–	–	–	–
Highly erodible	+	+	–	+	+	–
Steep & undulating topog	–	+	–	0	0	–
Odd shaped fields	–	0	+	+	+	+
Obstructions [1/]	–	0	0	–	0	0
Stony, cobbly	0	0	0	0	0	0
Water supply						
Low cont. flow	+	+	+	+	+	+
High intermit. flow	–	–	–	–	–	–
High salinity or sodicity	–	–	–	–	–	–
High sed. content	–	–	–	–	–	–
Delivery schedule						
continuous	+	+	+	+	+	+
rotation	–	–	–	–	–	–
arranged, flexible	0	0	0	0	0	0
demand	0	0	0	0	0	0
Climate						
High rainfall	+	+	+	+	+	+
Low rainfall—arid	0	0	0	0	0	0
Windy	–	–	–	–	–	–
High temp—humid	+	+	+	+	+	+
High temp—arid	–	–	–	–	–	–
Social/institutional						
Automation potential	–	–	–	+	+	0
Easy to manage	0	0	0	+	+	+

1/ Obstructions may include roads, buildings, rock piles, trees, above and below ground utilities, and oil pipelines.

Table 5–5 Factors affecting the selection of continuous/self moving [1/] sprinkler irrigation systems

Item	- - - - LEPA [2/] - - - center pivot	linear	- - - - LPIC [3/] - - - - center pivot	linear	- - Center pivot - - high press	low press	- - - - Linear - - - - high press	low press	gun
Crop									
Field—close growing	–	–	–	–	0	0	0	0	0
Field—row	0	0	0	0	0	0	0	0	0
Vegetable—fresh	0	0	0	0	0	0	0	0	0
Vegetable—seed	0	0	0	0	–	–	–	–	–
Orchard, berries, grapes	–	–	–	–	–	–	–	–	–
Alfalfa hay	–	–	–	–	0	+	0	+	0
Corn	0	0	0	0	0	0	0	0	0
Cotton	0	0	0	0	–	–	–	–	–
Potatoes, sugar beets	0	0	0	0	0	0	0	0	0
Land & soil									
Low AWC	+	+	+	+	+	+	+	+	0
Low infiltration rate	0	0	–	–	–	–	–	–	–
Mod. infiltration rate	0	0	0	0	–	–	0	0	0
High infiltration rate	+	+	+	+	+	+	+	+	+
Variable infiltration rate	+	+	+	+	+	+	+	+	+
High salinity and sodicity	0	0	0	0	0	0	0	0	0
Highly erodible	0	0	0	0	–	–	–	–	–
Steep & undulating topog	–	–	–	–	–	–	–	–	+
Odd shaped fields	–	–	–	–	–	–	–	–	+
Obstructions [4/]	–	–	–	–	–	–	–	–	+
Stony, cobbly	0	0	0	0	0	0	0	0	0
Water supply									
Low cont. flow rate	+	+	+	+	+	+	+	+	+
High intermit. flow rate	–	–	–	–	–	–	–	–	–
High salinity	–	–	–	–	–	–	–	–	–
High sed. content	–	–	–	–	–	–	–	–	–
Delivery schedule									
continuous	+	+	+	+	+	+	+	+	+
rotation	–	–	–	–	–	–	–	–	–
arranged, flexible	0	0	0	0	0	0	0	0	0
demand	0	0	0	0	0	0	0	0	0
Climate									
Humid & subhumid	+	+	+	+	+	+	+	+	+
Arid & semiarid	0	0	0	0	0	0	0	0	0
Windy	+	+	+	+	–	–	0	0	–
High temp—humid	+	+	+	+	+	+	+	+	+
High temp—arid	0	0	0	0	0	0	0	0	0
Social/institutional									
Automation potential	+	–	+	–	+	0	–	–	–
Easy to manage	0	0	0	0	0	0	0	0	0

1/ Continuous/self moving describes a sprinkler system that is self moving in continuous or start-stop operations.
2/ LEPA—Low Energy Precision Application system (in-canopy with good soil and water management).
3/ LPIC—Low Pressure In Canopy system.
4/ Obstructions may include roads, buildings, rock piles, trees, and aboveground utilities.

Table 5–6 Factors affecting the selection of micro irrigation systems [1/]

Item	Point source drip emitter	Line source cont. tube	Micro spray/ sprinkler	Basin bubbler
Crop				
Field—close growing	–	–	–	–
Field—row	–	0	–	–
Vegetable—fresh	–	+	–	–
Vegetable—seed	–	0	–	–
Orchards, berries, grapes	+	–	+	+
Alfalfa hay	–	–	–	–
Corn	–	0	–	–
Cotton	–	+	–	–
Potatoes, sugar beets	–	0	–	–
Land & soil				
Low AWC	+	+	+	+
Low infiltration rate	0	0	0	0
Mod. infiltration rate	0	0	0	0
High infiltration rate	+	+	+	0
Variable infiltration rate	+	+	+	+
High salinity and sodicity	0	+	+	0
Highly erodible	+	+	+	0
Steep & undulating topog	+	–	+	–
Odd shaped fields	+	+	+	+
Obstructions [2/]	+	+	+	+
Stony, cobbly	+	+	+	+
Water supply				
Low cont. flow rate	+	+	+	+
High intermit. flow rate	–	–	–	–
High salinity	–	–	–	–
High sed. content	–	–	–	–
Delivery schedule				
continuous	+	+	+	+
rotation	–	–	–	–
arranged, flexible	0	0	0	0
demand	0	0	0	0
Climate				
Humid & subhumid	0	0	0	0
Arid & semiarid	0	0	0	0
Windy	+	+	–	0
High temp—humid	0	0	0	0
High temp—arid	0	0	0	0
Social/institutional				
Easy to manage	–	–	–	–
Automation potential	+	+	+	+

1/ Not suitable unless water supply is non-saline, low SAR, and very high quality.
2/ Obstructions may include roads, buildings, rock piles, trees, and below-ground utilities.

Table 5–7 Factors affecting the selection of subirrigation systems [1/]

Item	Water table control	Item	Water table control
Crop		**Water supply**	
Field—close growing	0	Low cont. flow rate	+
Field—row	0	High intermit flow rate	–
Vegetable—fresh	0	High salinity	–
Vegetable—seed	0	High sed. content	–
Orchards, berries, grapes	0		
Alfalfa hay	–	**Delivery schedule**	
Corn	0	continuous	+
Cotton	–	rotation	–
Potatoes, sugar beets	0	arranged, flexible	–
		demand	0
Land & soil			
Low AWC	0	**Climate**	
Low permeability	0	High rainfall	+
Mod. permeability	+	Low rainfall—arid	–
High permeability	0	Windy	+
Variable infiltration rate	0	High temp—humid	+
High salinity and sodicity	–	High temp—arid	+
Highly erodible	0		
Undulating topography	–	**Social & institutional**	
Odd shaped fields	0	Easy to manage	0
Obstructions [2/]	0	Automation potential	0
Stony, cobbly	–		

1/ Not suitable unless water supply is nonsaline, low SAR, and very high quality.
2/ Obstructions may include roads, buildings, rock piles, trees, and belowground utilities.

Table 5–8 Slope limitations for surface irrigation systems (after grading)

Type	Maximum slope(%) (arid & semiarid areas) non-sod	sod	Maximum slope(%) (humid areas) non-sod	sod
Level				
basin/border	- - - - - - - - - - - - Flat - - - - - - - - - - - -			
furrow	- - - - - - - - - - - - Flat - - - - - - - - - - - -			
Graded				
border	2.0	4.0	0.5	2.0
furrow	3.0		0.5	
corrugation	4.0	8.0		
contour levee	0.1			
contour ditch	4.0	15.0		
contour furrow	Irrigated cross slope			

Table 5–9 Slope limitations for sprinkler irrigation systems

Type	Maximum slope (%) 1/	Comments
Periodic move/set		
portable handmove	20 +/–	Laterals should be laid cross slope to minimize and control pressure variation. Consider using pressure or flow control regulators in the mainline, lateral, or individual sprinkler/ spray heads, when pressure differential causes an increase of > 20 % of design operating pressure.
sideroll - wheel mounted	10	
gun type	20 +/–	
end tow	5 - 10	
Fixed (solid) set		
permanent laterals	no limit	
portable laterals	no limit	
gun type	no limit	
Continuous move		
center pivot	15	
linear move	15	
gun type	20 +/-	
LEPA		
center pivot	1.0	
linear	1.0	
LPIC		
center pivot	2.5	
linear	2.5	

1/ Regardless of type of sprinkler irrigation system used, runoff and resulting soil erosion becomes more hazardous on steeper slopes. Proper conservation measures should be used; i.e., conservation tillage, crop residue use, filter strips, pitting, damming-diking, terraces, or permanent vegetation.

652.0505 State supplement