Irrigation for Hazelnut

Xinhua Jia, Ph.D., P.E.

Professor of Department of Agricultural & Biosystems Engineering
North Dakota State University, Fargo, ND

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Irrigation

Irrigation is the supply of water to crops by artificial means.

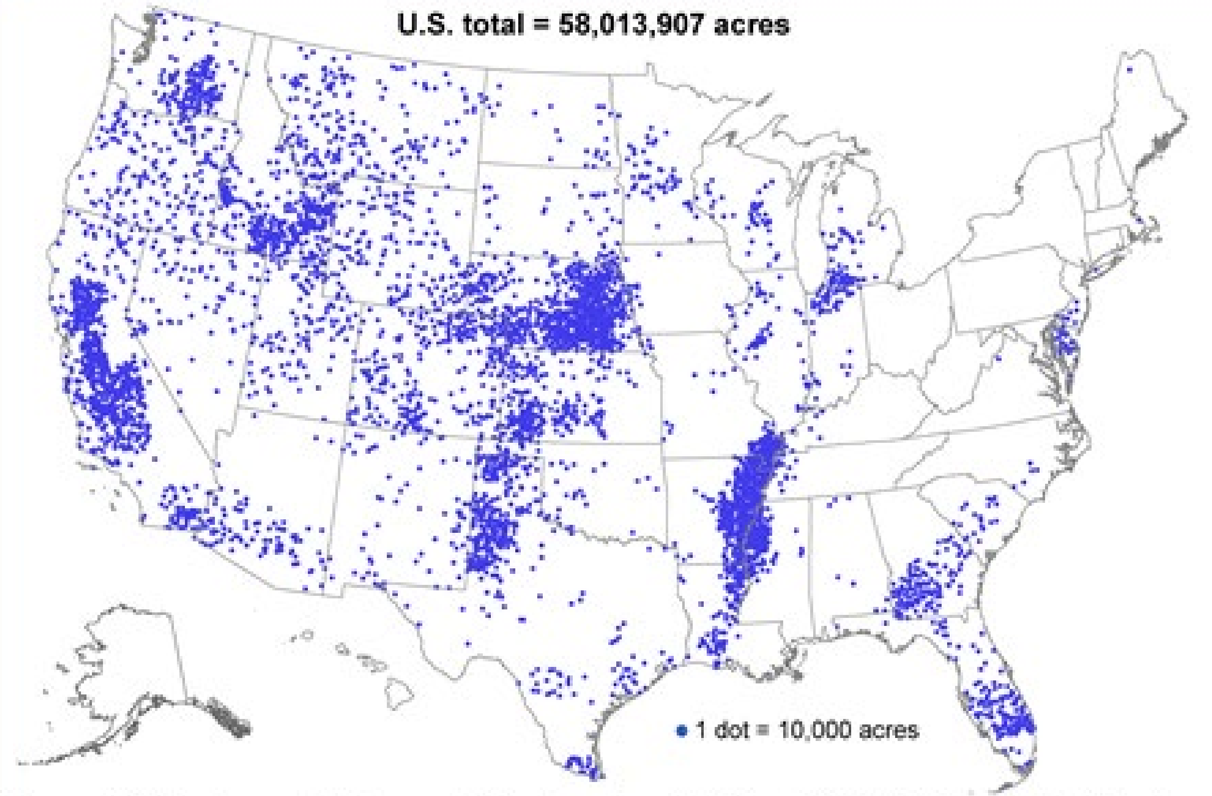
Table 1.1. Worldwide distribution of irrigated areas in 2017 (adapted from FAO, 2021).

	Irrigated Area (millions of acres)	Percent of Cropped Lands	Percent of World Total
Asia	574	39	71
America	128	14	16
Europe	56	8	7
Africa	39	6	5
Oceania	8	10	1
World	806	21	100

(Eisenhauer et al., 2021)

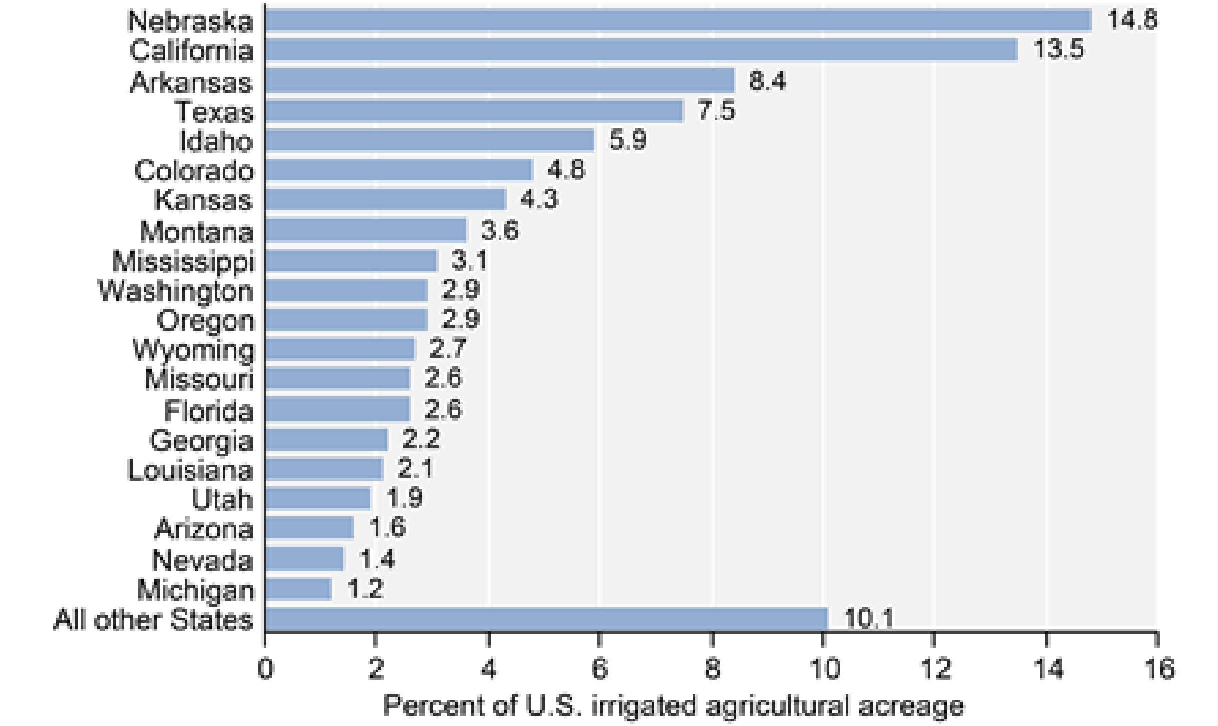
Irrigated Agricultural Land in U.S.

U.S. acres of irrigated land by county, 2017



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, 2017 Census of Agriculture.

State shares of U.S. irrigated agricultural land, 2017



Note: The 20 leading States account for 89.9 percent of all irrigated acres in 2017, including harvested cropland, pasture, and other lands (but excluding horticulture under protection).
Source: USDA, Economic Research Service using USDA, National Agricultural Statistics Service, 2017 Census of Agriculture.

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[USDA ERS - Irrigation & Water Use]

Benefits of Irrigation

- Stabilized farm income
- Increased crop yields and quality
- Frost protection
- Crop cooling
- Efficiency of resource use

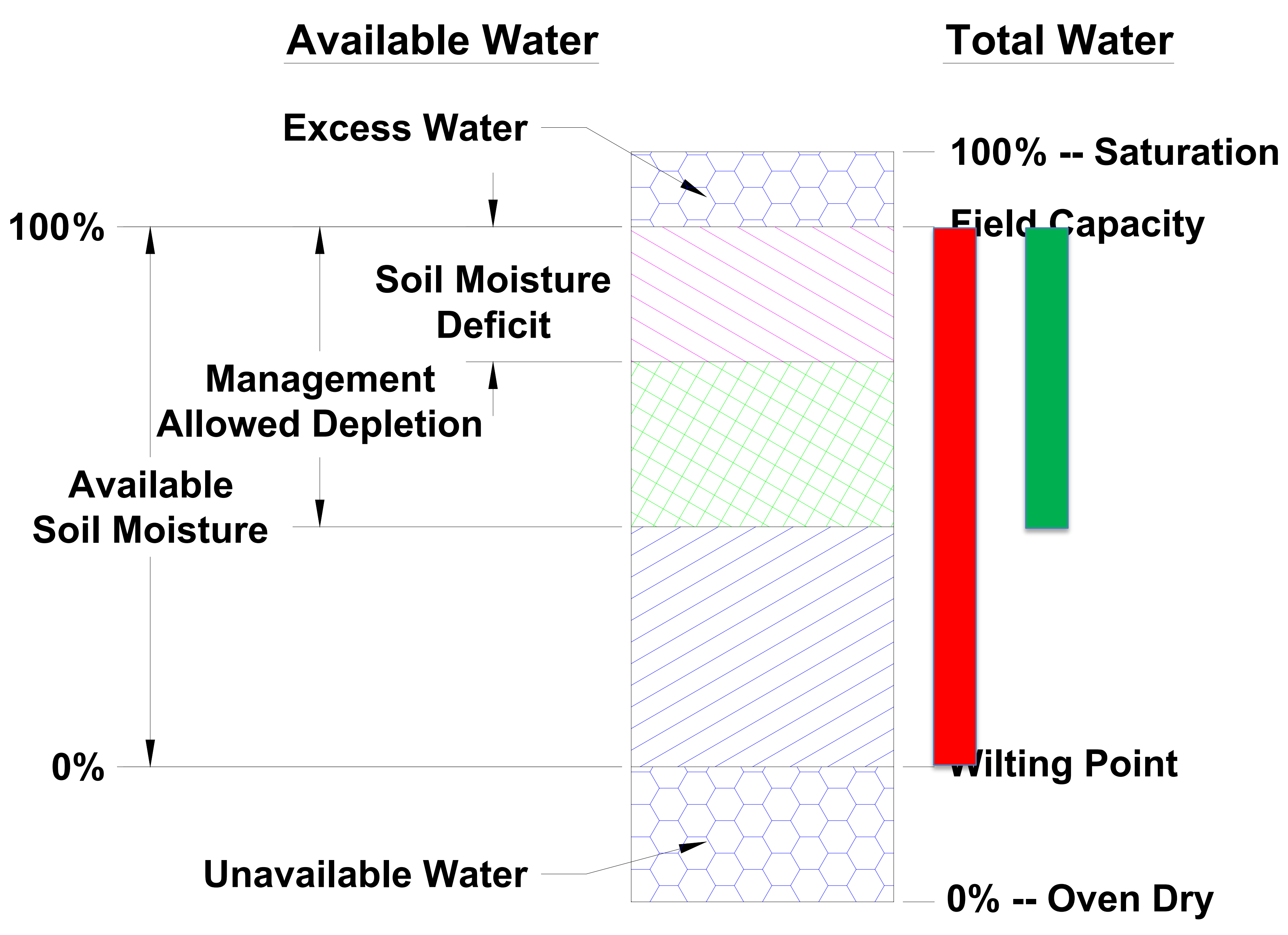
Drawbacks of Irrigation

- Costs
  - Equipment
  - Management
  - Operation
- Potential adverse environmental impacts
  - Water consumption
  - Soil degradation, salt movement, secondary soil salinity
  - Waterlogging of soils

Irrigation Scheduling

- When to irrigate
  - Plant indicators
  - Soil indicators
  - Water balance techniques
- How much to irrigate
  - Soil water measurements
  - Water balance techniques

(Schwab et al., 1996)



Available Water
Total Water
Excess Water
100% -- Saturation
100%
Field Capacity
Soil Moisture Deficit
Management Allowed Depletion
Available Soil Moisture
0%
Wilting Point
Unavailable Water
0% -- Oven Dry

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Water Balance Equation

$$D_i = D_{i-1} + (ET - P_e)_i$$

D = soil water deficit, inches

ET = evapotranspiration, inches

P_e = effective precipitation

i = end of today

i-1 = end of yesterday

Crop Water Consumption - Evapotranspiration (ET)

Depends on

- Crop type
- Stage of development
- Soil water status
- Atmospheric conditions (T, RH, U, & Rn → Reference ET = ET_{ref})

} Crop coefficient (K_c)

$$ET = K_c \, ET_{ref}$$

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Irrigation methods

Subsurface irrigation

- Subirrigation: water was applied below the soil surface
- Subsurface drip irrigation systems

Surface irrigation

- Surface irrigation
  - Flood, furrow, level basin, graded basin.
- Sprinkler irrigation
  - Center pivot, linear move, big gun, micro-jet, solid set.
- Trickle/micro/drip irrigation

Choose the right system --Table 15.2

1. Infiltration rate
2. Topography
3. Crops
4. Water supply
5. Water quality
6. Efficiency
7. Labor requirement
8. Capital requirement
9. Energy requirement
10. Managements skill
11. Machinery operations
12. Duration of use
13. Weather
14. Chemical application

Must be a *system* approach & all aspects are interrelated

Efficiency, Uniformity, Design, Scheduling, Equipment, & Maintenance

(Troeh et al., 2004)

Drip Irrigation

A method of irrigation that delivers slow, frequent applications of water to the soil using a low pressure distribution system.

- Usually delivers water to individual plants
- Outlets placed at short intervals along a small plastic tube
- Also knows as micro or trickle irrigation, bubblers, localized small micro-sprinklers, micro-spinners, and micro-sprayers.

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[USDA NRCS - Natural Resources Conservation Service]

Drip Irrigation Pros and Cons

Pros: High Efficiency

- Only soil around the plant is watered
- Deep percolation losses are decreased
- Minimal evaporation

Cons: Management

- Typically only delivers the amount of water that is used by ET or depleted from the root zone
- There is little room for error - you can not "get behind"
- High water quality requirement

Drip Irrigation Types (*Eisenhauer et al., 2020*)

(a) Surface drip: water applied slowly through small emitter openings to the soil surface.

(b) Microspray: water sprayed over the soil surface at relatively low pressure (also called microsprinkler)

(c) Bubbler: a small stream of water applied to flood the soil surface in localized areas.

(d) Subsurface drip: water applied through emitter openings below the soil surface.

Figure 14.1. Examples of microirrigation systems: (a) surface drip (photo courtesy of Toro); (b) microspray (photo courtesy of Texas International Irrigation); (c) bubbler (photo courtesy of Anchor Commodities); and (d) subsurface drip (photo courtesy of Freddie Lamm, Kansas State University).

Surface vs. Subsurface Drip

Feature	Surface Drip Irrigation (SI)	Subsurface Drip Irrigation (SDI)
Installation	On the soil surface, easier to install and modify	Below the soil surface, requires more precise installation
Water Efficiency	High efficiency, with some loss from evaporation	Highest efficiency, minimal evaporation losses
Maintenance and durability	More susceptible to damage, easier to maintain	Less susceptible to damage, but difficult to maintain - inaccessibility
Crop suitability	Suitable for a wide variety of crops and garden layouts	Best for perennial crops and less ideal for annual crops
Cost	Lower initial costs	Slightly higher initial costs during installation
Soil and Environmental Considerations	Good for a range of soil types, emitter spacing critical for uniform distribution	Less soil erosion and nutrient runoff, especially in sandy soils or high evaporation areas

Typical Drip Equipment

A drip installation may use all or some or all these parts

- Emitters control water flow and placement
- Laterals deliver water to the emitters
- Main and Submains deliver water to the laterals
- Water Control Station
  - Water Source, Pump, Valves
  - Filters, Pressure Regulators, Pressure Gages

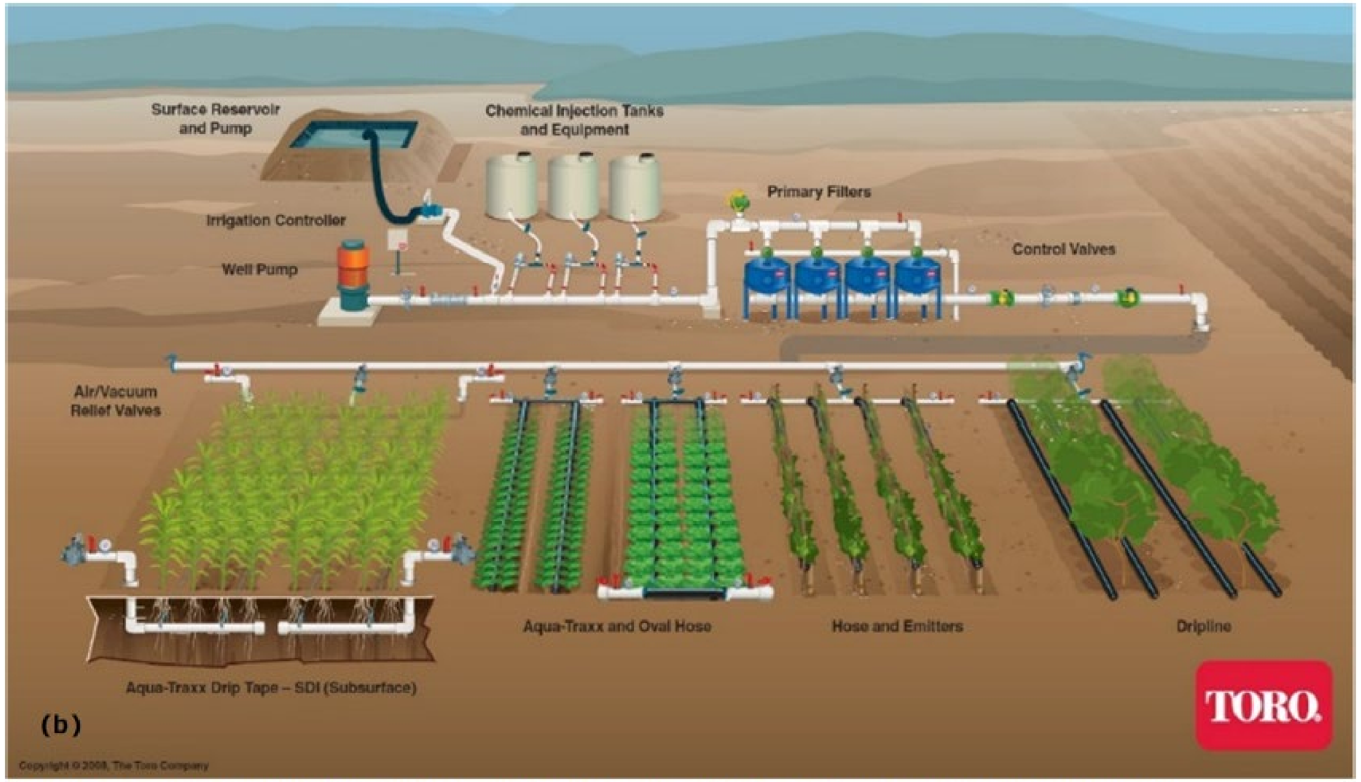

Figure 14.5. Basic components of (a) a control station and (b) an entire microirrigation system. (Image courtesy of Toro.)

(Eisenhauer et al., 2020)

Table 2. Guidelines to assess water suitability for irrigation.

Water Quality Constituent	Class 1	Class 2	Class 3	Class 4
Salinity (Electrical Conductivity – EC) (dS/m)	0-0.4	0.4-0.9	0.9-2.7	2.7-5.4
Salinity (Electrical Conductivity – EC) (dS/m)	0-1.5	1.5-3.0	3.0-5.0	5.0- 10.0
Sodicity (SAR)	0-0.2	0.2-0.9	0.9-1.5	1.5-3.0
Boron (mg/l)	0-105	105-140	140-350	>350
Chloride (Cl) (mg/l)	0-70	70-115	115-160	160-200
Sodium (Na) (mg/l)	0-5	5-30	>30	
Nitrogen (mg/l as N)	< 0.05	0.05-5	5-10	10-20
Manganese (Mn) (mg/l)	<0.05	0.05-0.2	0.2-5	5-10
pH (acceptable range)	6.5-8.4			

(USAID, 2019)

Table 6. In farm water treatments according to different types of irrigation water.

Treatment	Characteristic	Water source
Sedimentation tank	high concentration of suspended solids sedimentable inorganic	surface (canals, rivers)
	presence of iron	well
Hydro-cyclone filter	with high concentration of sand	well and river
Mesh filter or disks	with solid in suspension inorganic	surface, well and wastewater
Sand or grit filter	with high concentration of solids suspended organic and inorganic	surface and waste
Chemical treatment of acidification	presence of bicarbonates and iron	well
	development of microorganisms	surface and well
Chemical treatment with chlorination	presence or possibility of development of microorganisms (ferro bacteria, sulfur bacteria, etc.)	surface, well and waste

Figure 36. Mesh filters (From: Arkal)

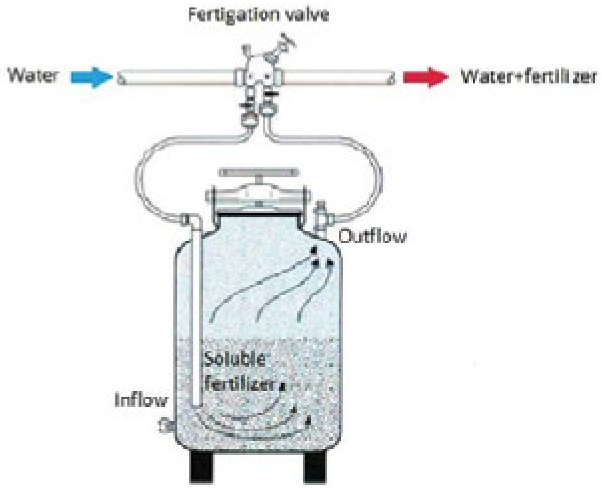

Figure 51. Fertilizer injection based on pressure differential between inlet and outlet. Fertilizer tank made of anti-corrosive material

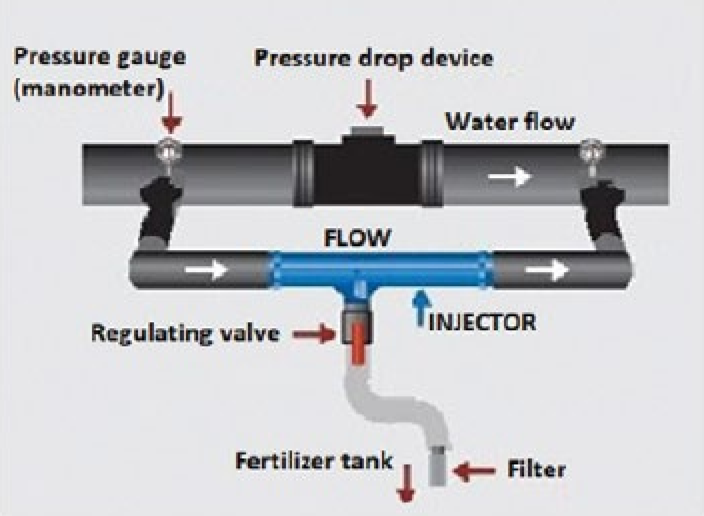

Figure 52. Venturi injector working principle

Figure 53. Fertilizer injection calibrated by a dosing pump under the command of the fertigation control unit.

Figure 54. Highly automated fertigation bank (From: Agricolplast website).

Water Distribution on Different Soils

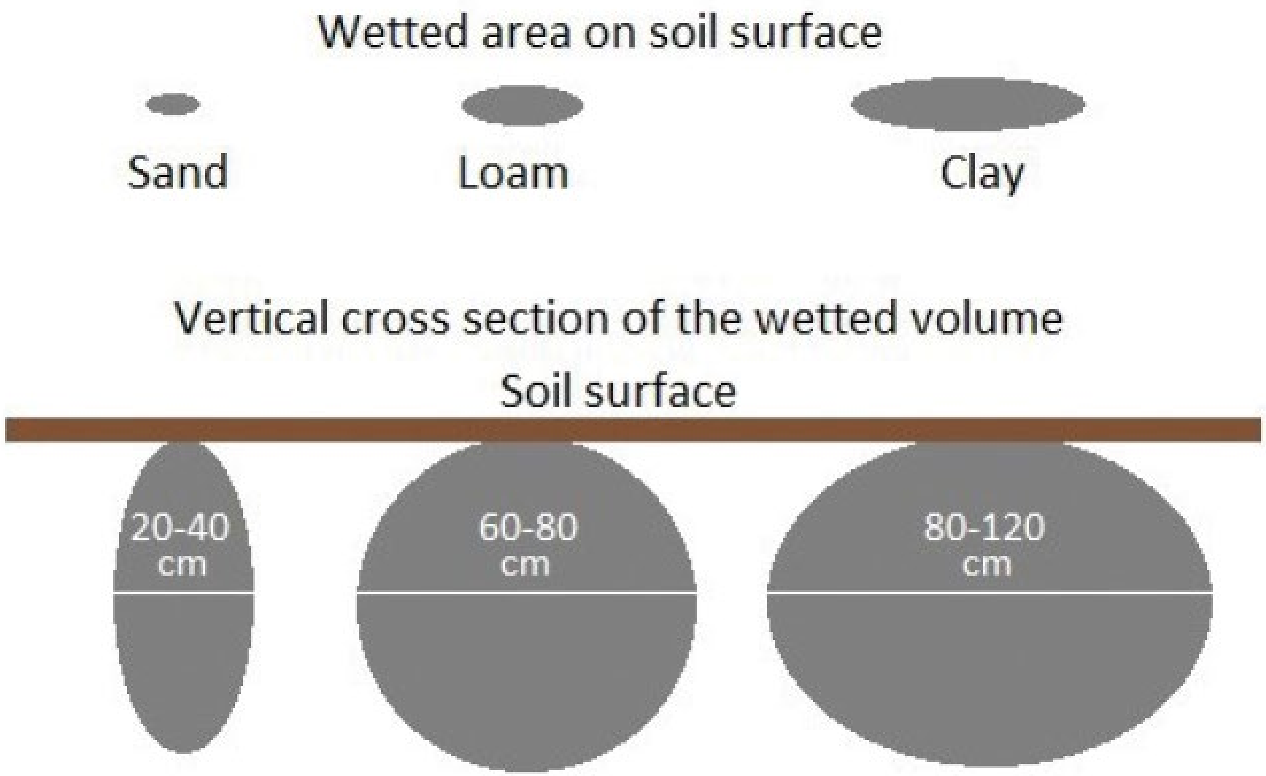

Figure 8. Typical water distribution patterns under drip irrigation in different soils. Due to the lower emitter discharge of drippers, the standing time is usually longer, and the farmer's operating system should be able to accommodate the choice.

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(USAID, 2019)

Drip Irrigation Design

Step 1: Site and Crop Evaluation

1) Soil Analysis: Soil type and texture, water holding capacity, & hydraulic conductivity (Web Soil Survey)
2) Topography: Topography of the field (LiDAR map)
3) Climate Conditions: Rainfall, reference ET, temperature, frost days (weather stations)

4) Water Source: Identify your water source (well, river, municipal water, etc.), and test water quality for salinity or other elements.

Drip Irrigation Design (Cont.)

Step 2: Hazelnut Water Requirements

• Water Consumption (ET): Depends on growth stages, soil type, and climate conditions, with and without grasses → ET_{ref} is your maximum

• Root Depth: Affect emitter selection and watering schedules

Step 3: System Design Components

•Drip Tubing: Can handle the water flow rate that are suitable for your soil type and hazelnut trees' water demands

•Emitters: Flow rate good for deep watering (1 to 4 gallons per hour emitters)

•Filters and Pressure Regulators: To prevent clogging and pressure regulators to maintain consistent water pressure throughout the system.

Drip Irrigation Design (Cont.)

Step 4: Layout Planning

- Tree Spacing: Decide on the number of drip lines needed and the spacing between emitters.
- Drip Line Placement: Install drip lines along both sides of the tree rows to ensure even water distribution to the root zone.
- Main and Sub-main Lines: Design the layout of main and sub-main lines to distribute water efficiently from the source to all parts of the orchard.

Step 5: Installation Guidelines

- Depth: Surface installation with mulch cover or shallow burial is effective.
- System Testing: After installation, test the system for leaks, proper emitter function, and uniform water distribution.

Drip Irrigation Design (Cont.)

Step 6: Management and Maintenance

• Irrigation Scheduling: Develop an irrigation schedule based on soil moisture monitoring, weather conditions, and the growth stage of the hazelnuts, adjusting as needed.
• Regular Maintenance: Inspect and clean filters regularly, check for leaks or damage, and flush the system periodically to prevent clogging.

Step 7: Monitoring and Adjustment

• Soil Moisture: Use soil moisture sensors or manual checks to monitor soil moisture levels, ensuring they meet the needs of growing hazelnuts.
• Adjustments: Be prepared to adjust the irrigation schedule and system setup as the trees grow and conditions change.

Table 20. Indicative maintenance operations for drip systems

Monitor	Every cycle	Monthly	Yearly
Inspect system for leaks and calcium carbonate precipitation	✓		
Check pressure difference across filters and system operating pressure	✓		
Adjust filter back flush cycle		✓	
Flush laterals (depending on water quality)		✓	
Clean filters thoroughly		✓	
Monitor pressure at lateral outlets		✓	
Monitor air valves and pressure control valves			✓
Monitor system flow (main flow meter)	✓		
Check hydraulic and electrical connectors			✓
Check hydraulic valves and filters to inspect moving parts			✓
Replace sand in sand filters			✓
Chlorine treatment (depending on water quality and application method)			✓
Take water samples at end of the laterals and evaluate changes in water quality			✓

Soil Compaction

Soil compaction is the increase in soil bulk density, and decrease in soil porosity caused by heavy loads when too wet. Soil compaction decreases water infiltration, increase runoff and restricts root growth.

A soil penetrometer is one tool to check soil compaction depth. Source: NRCS Grigar Midland County

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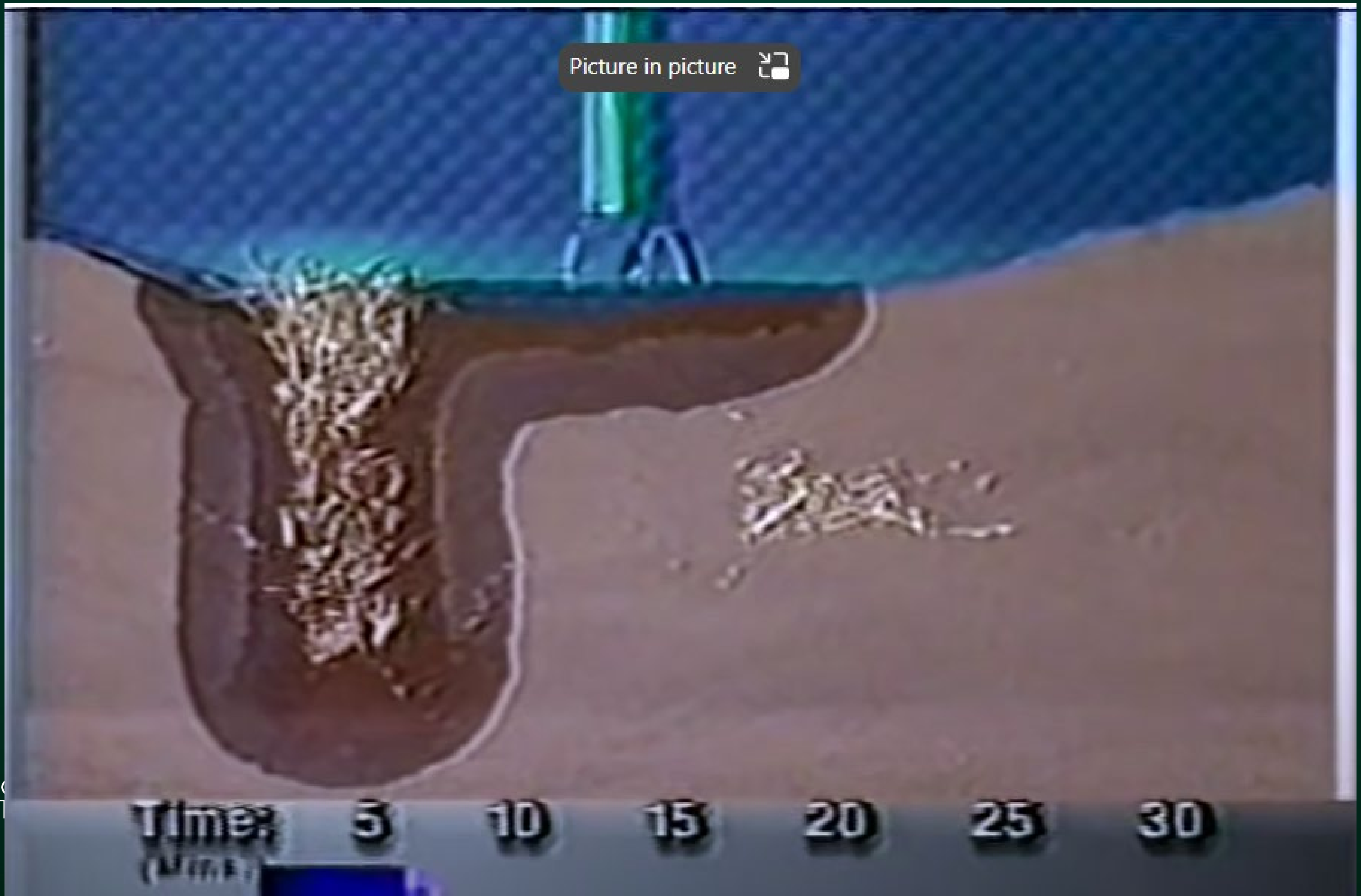
Natural Resources Conservation Service (NRCS) 324.1. Soil Compaction Symptoms, Causes, Correction, & Prevention, 2019. 646 Job Sheet (usda.gov)

Water Movement in Soil

[Water Movement In Soils (youtube.com)](#)   [002 How Water Moves Through Soil (youtube.com)](#)



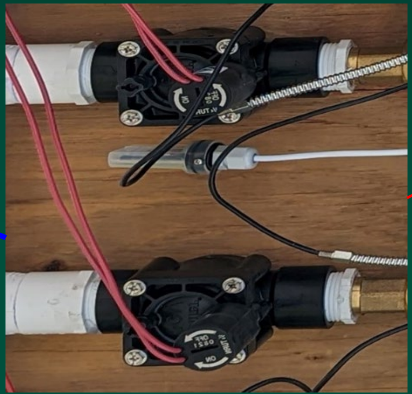
How to Manage the Drip Irrigation?

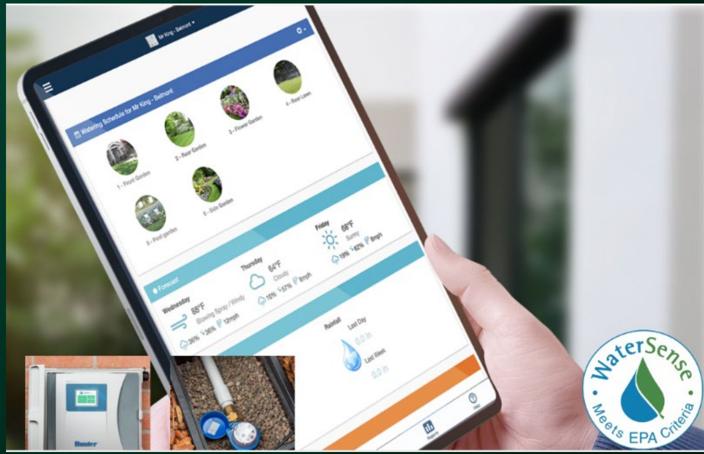
- Manually: Turn on/off the irrigation manually every day when it is not rained?
- Timer: Turn on/off the irrigation at a fixed time and for a fixed duration?
- Irrigation scheduling: water balance or energy balance
- Controller: Turn on/off the irrigation based on crop, or soil, or weather conditions automatically? Remotely manage with your phone?

Smart Water Management Research

- Automatic
- Sensor Incorporated
- Remote Controlled
- Precise with higher efficiency
- Flexible Irrigation Scheduling
- Labor/Cost Saving

Smart irrigation system in the field





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Call me: 701-231-6453

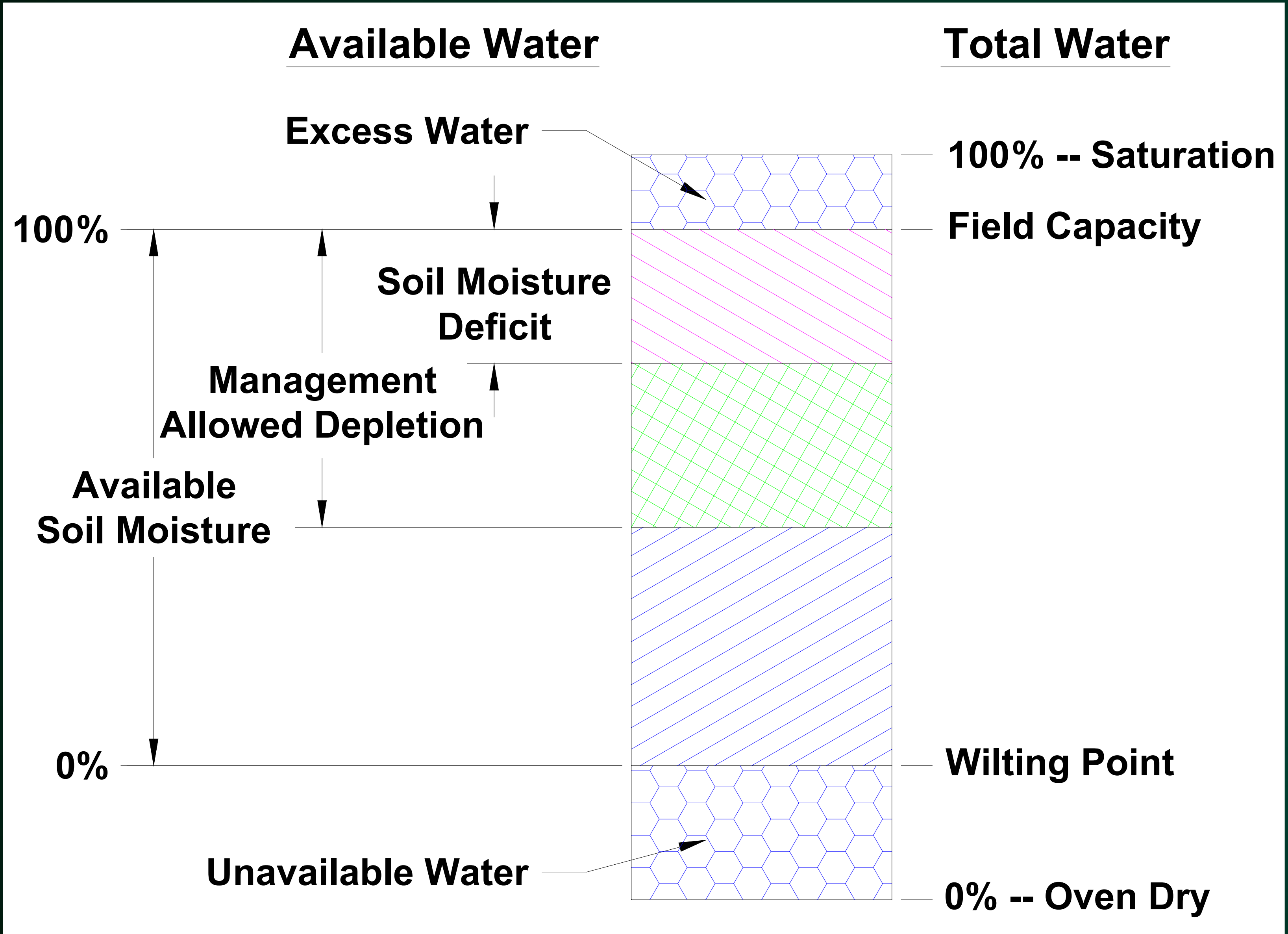
Email me: Xinhua.Jia@ndsu.edu

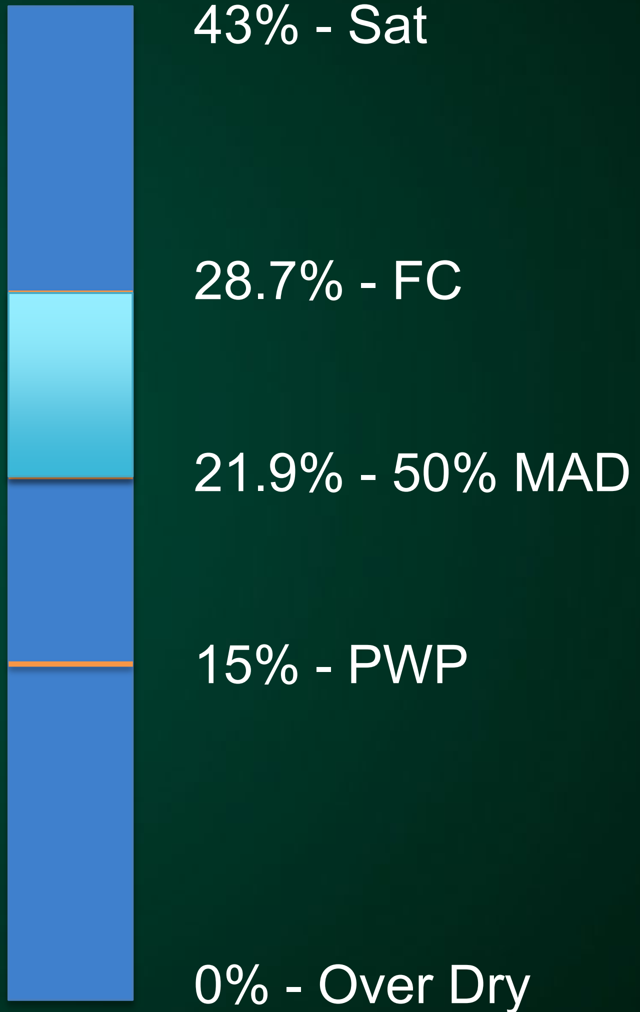
Description of the site

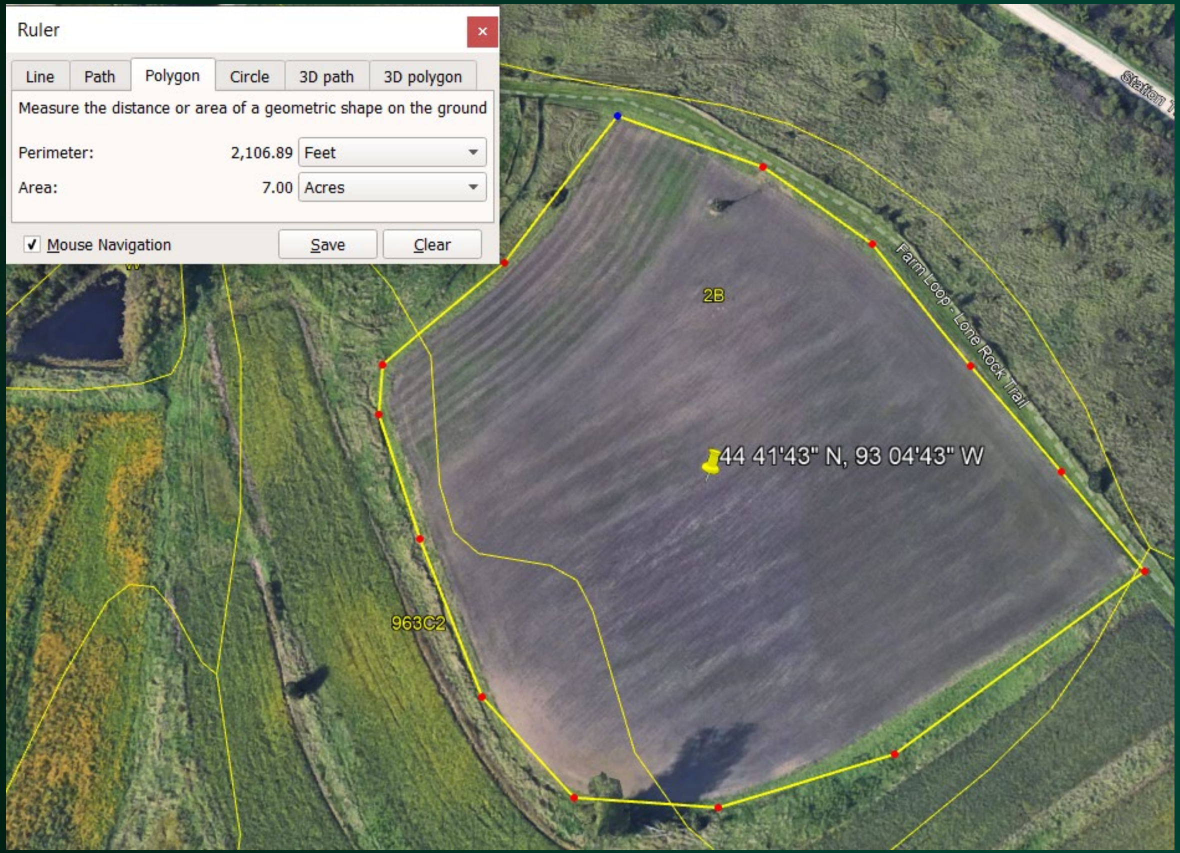
Sites that probably don't need irrigation except during establishment or extreme drought.
UMORE Park, Rosemount, Minnesota, 44 41'43" N, 93 04'43" W

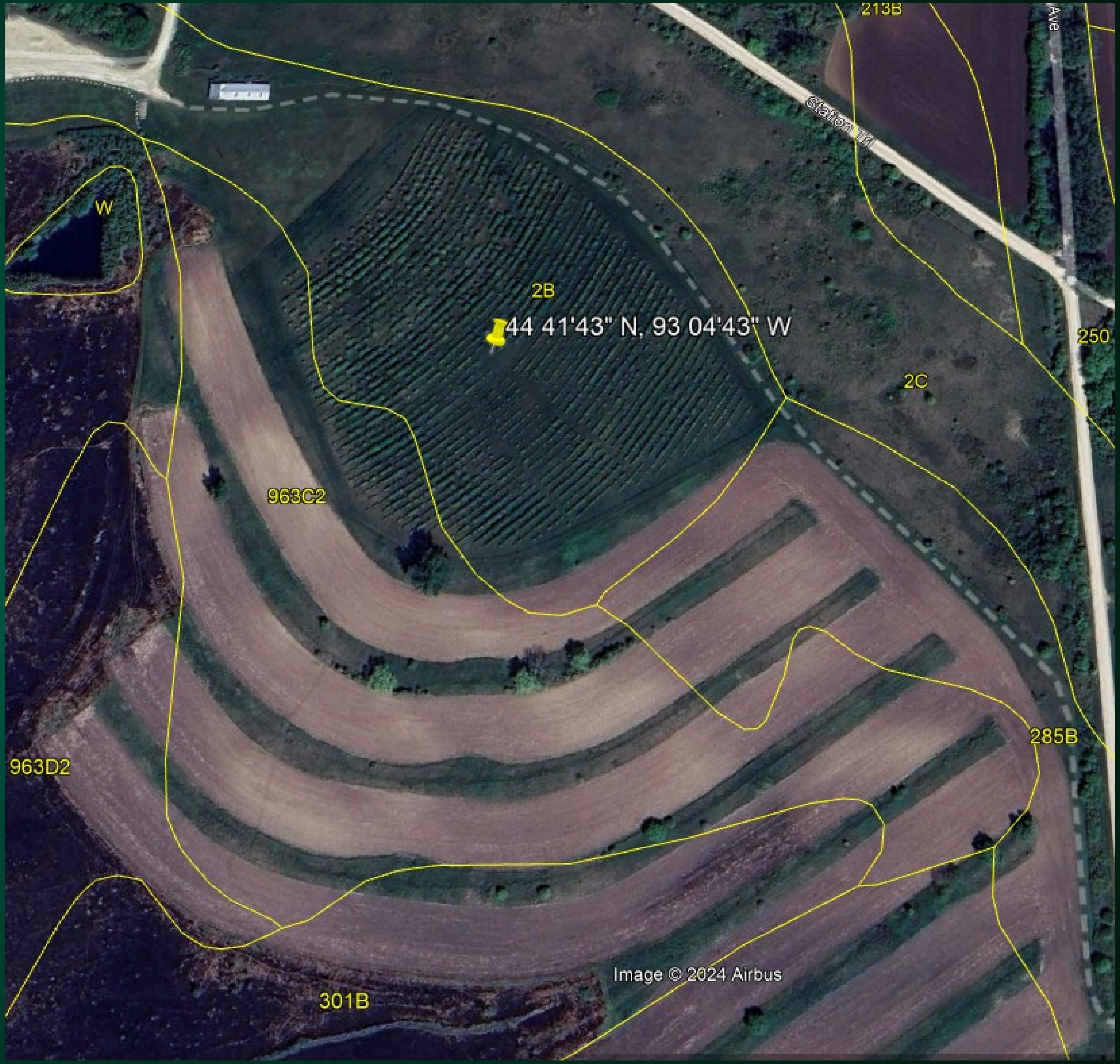
Ostrander silt loam, 1-6% slope. This 7 acre field is shaped like a shallow bowl on a gentle hillslope. Because it is underlain by an impervious layer of clay, water collects in the center. Three years ago, when we had a string of extremely wet years, the hazelnuts in the center of the field seemed to be drowning, and many died, but now, after three years of drought, those that survived are recovering. The hazelnuts on the higher ground around the edges are doing very well with no irrigation, in spite of the drought.

Parameter	Values
Soil type	Loam
Precip	23-35 in/yr
Restrictive layer	>80 in
Bulk density	1.53 g/cm^3
Field capacity	28.7%
PWP	15%
Available water	13.7% → 4.9 in per 3 ft
Management allowed depletion	50% → 2.5 in per 3 ft


Available Water
Total Water
Excess Water
100% -- Saturation
100%
Field Capacity
Soil Moisture
Deficit
Management
Allowed Depletion
Available
Soil Moisture
0%
Wilting Point
Unavailable Water
0% -- Oven Dry


43% - Sat
28.7% - FC
21.9% - 50% MAD
15% - PWP
0% - Over Dry





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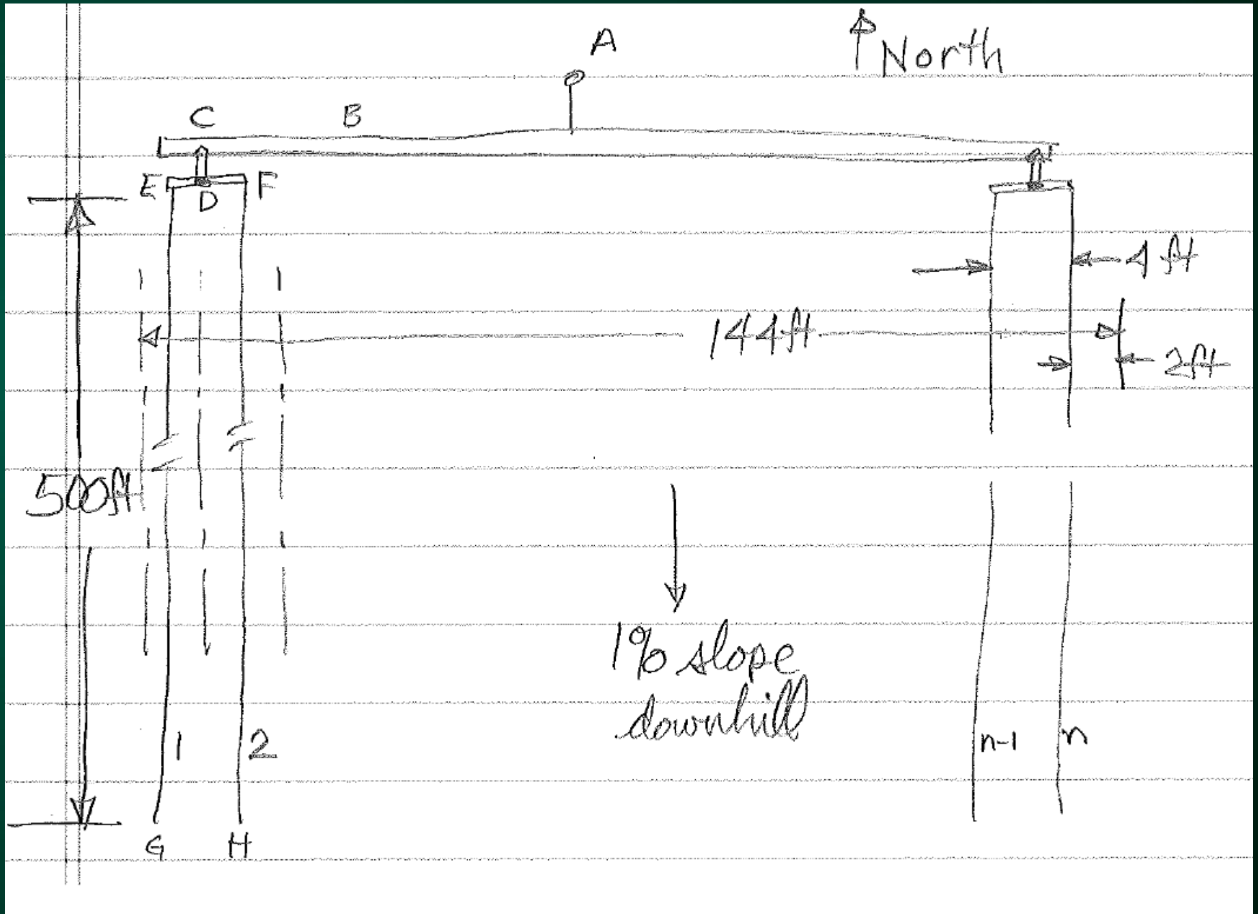
Drip Irrigation Design Example

Given:
Drip tape on 4-ft centers is used to irrigate winter squash. The field is 500 ft long and 144 ft wide with 1% slope along its length (tape will run downhill). A submersible pump can produce 35 gpm at 35 psi and 70% efficiency from a 30-ft well at the top (high) end of the field. The soil is a Maddock sandy loam and the site is near Oakes, ND.

Find:
a) a suitable drip tape and the length needed.
b) the number of irrigation zones.
c) the time of irrigation for each zone that will meet peak water requirements.



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Assumptions:

1. Pump pressure is adequate because regulators at each subheader (point D) are set at 10 psi. (We could work through the pipe hydraulics, pump sizing, etc.)
2. Each zone will be irrigated every day.
3. Peak ET is 0.30 inch/day.

Calculations:

1.a. n = number of tapes = field width / tape spacing = 144 ft / (4 ft/line) = 36 lines.

1.b. Total length of tape = n x field length = 36 lines x 500 ft = 18,000 ft.

2. Assume a drip tape rated at 0.5 gpm/100 ft, with 12-inch emitter spacing (Chapin).

3. Flow rate per tape is q_i = (0.5 gpm/100 ft) x (500 ft / line) = 2.5 gpm per line.

4. Total flow of all lines is $Q_T = n\ q_i$ = (36 lines) (2.5 gpm / line) = 90 gpm

This exceeds the pump capacity, so we need to divide the irrigated area into zones of irrigation.

5. Number of zones is z = (Irrigation system flow rate) / (Pump capacity) = 90 gpm / 35 gpm = 2.6

Round up to z = 3 zones.

6. Lines per zone = n / z = 36 lines / 3 zones = 12 lines per zone.

7. Area per zone:

A_z = (# of lines) x (tape or line spacing) x (field length)

= (12 lines) (4 ft spacing/line) (500 ft) = 24,000 ft^2

8. Volume of water needed per zone per day = area x depth

Vz = (Az) (d) = (24,000 ft^2) [(0.30 in ET/day) (1 ft / 12 in)]

= 600 ft^3 x 7.48 gal/ft^3 = 4488 gal.

9. Pumping rate per zone Qz = z qi = (12 lines/zone) (2.5 gpm / line) = 30 gpm / zone

The pump capacity is 35 gpm, so the zone size and tape flow rate are acceptable.

10. Time needed to irrigate one zone is found from

$Qz = Vz / t_z$ or $t_z = Vz / Qz$ = (4488 gal/zone) / (30 gal/min) = 149.6 min./zone

t_z = 149.6 min / zone x (1 h / 60 min) = 2.49 h / zone or about 2.5 h / zone

11. Time needed to irrigate all zones is

$t_{field} = z\ t_z$ = (3 zones) (2.5 h /zone) = 7.5 hours

This is possible because it is less than 24 hours and we wanted to irrigate the whole field once per day.

12. Volume of water needed per day is

$V_T = z\ V_z$ = (3 zones) (4488 gal) = 13,464 gal

13. Recommendations:

a. Irrigate each zone 2.5 hours per day. This could be done in one continuous set, or each zone could be split into several shorter sets to maximize capillary action in the soil. Irrigating in one set may saturate the soil around the emitters, leading to gravitational movement of water downward.

b. Install solenoid-activated valves to route the water to each zone.

c. Use a controller to start and stop the pump, control the valves, etc.

d. Install a flow meter to monitor system performance.

Check for potential problems, such as emitter plugging or leaks.

An alternative to irrigation based on time alone is to set up some logic to irrigate based on the time expected for irrigation and the volume of water needed per zone.

e. Install proper filtration and backflow prevention devices. Select components that will not "consume" too much pressure.

f. Test the water quality. High pH and high bicarbonate (HCO_3^-) may require acid injection to prevent emitter plugging.

g. Drain and properly winterize the system each fall.

Suggestions for improvement in the design:

1. Specify the pump last, not first. In this case, we were given a site to irrigate and had to use what was available.
a. Pump sizing for flow rate
b. The well yield or capacity
c. Design the pipeline and drip tape pressure requirements and friction losses.
d. Select a pump based on both flow rate (Q) and head (H).

2. Why irrigate every day?
a. Smaller applications allow more capillary action of water movement in the soil.
b. Deficit irrigation can be controlled more precisely.

3. How is irrigation volume computed?
a. Depth per unit total area. Conventional ET calculations and irrigation scheduling can be used.
b. Depth per unit wetted area.