Module 6: Water Withdrawals, Uses, and Agricultural Irrigation

1. Water Withdrawals and Uses

Water for Energy Production

- **Thermal Power:** Water is essential for cooling processes in fossil fuel and nuclear power plants.
- **Hydropower:** Utilizes the potential and kinetic energy of water stored in reservoirs or flowing in rivers to generate electricity; hydropower plants primarily return water to the flow after use[1] [2].
- **Conflicts:** Storage reservoirs designed for hydroelectric generation, irrigation, and flood control must balance conflicting needs—in particular, keeping reservoirs full for energy/irrigation versus maintaining empty space for flood protection[3].

Water for Agriculture

- **Largest User:** Agriculture consumes about 70% of freshwater withdrawals globally, mainly for irrigation[4].
- **Uses:** Irrigation, pesticide and fertilizer application, livestock, and food processing.
- **Environmental Concerns:** Overuse and poor management can reduce river flows, raise soil salinity, and damage wetlands[4].

Water for Flood Control

- Reservoirs and dams are managed to store excess water during heavy rainfall, reducing downstream flood risk.
- **Challenge:** Flood control requires empty storage capacity, which may conflict with full reservoirs needed for irrigation or power[3] [5].

2. Analysis of Surface Water Supply

- **Assessment** includes measurement of river flows, rainfall, runoff, and storage in lakes or tanks. Modern techniques include real-time monitoring, hydrological modeling, and seasonal demand forecasting.
- **Surface water supply** is compared to all consumptive demands to manage shortages, plan allocation, and implement conservation measures[6].

3. Water Requirement of Crops in India

Crops and Crop Seasons

- **Kharif (monsoon; June–Oct):** Paddy (rice), maize, millet, sorghum, cotton, groundnut—sowing aligns with monsoon onset.
- **Rabi (winter; Oct–March):** Wheat, barley, chickpea, mustard, peas—sown after the withdrawal of the monsoon.
- **Zaid (summer; March–June):** Short-duration crops like watermelon, vegetables, and some pulses[7].

Cropping Pattern

- Refers to the proportion and sequence of various crops grown in a region or farm.
- Choices are influenced by water availability, climatic conditions, soil type, and socio-economic considerations.

4. Duty and Delta

Term	Definition	Typical Values (India)
Delta	Total depth of water (in cm) required by a crop during its base period	Paddy: 120–140cm, Wheat: ~50cm
Duty	Area (in hectares) irrigated per unit flow (1 cumec) of continuous water	Paddy: 400–800 ha/cumec[8] [9]

- **Duty**: Increases with better irrigation methods, land leveling, and efficient designs.
- **Delta**: Varies with crop, climatic zone, and crop duration.

5. Quality of Irrigation Water

Water quality impacts crop yield and soil health.

- **Parameters**:
  - **Salinity:** Measured as Electrical Conductivity (EC). C1 (0–0.25 dS/m) and C2 (0.25–0.75 dS/m) classes are suitable for irrigation; higher classes cause salinity problems[10].
  - **Sodicity:** High sodium concentration damages soil structure. Evaluated through Sodium Adsorption Ratio (SAR) and related indices.
  - **Alkalinity & Specific Ion Toxicities:** High residual sodium carbonate (RSC), chloride, boron, and nitrate affect crops and soil[10].
- **Water with C3/C4 salinity or high SAR/RSC is generally unsuitable without special management.**

6. Soil-Water Relationships

- **Root Zone Soil Water:** The soil layer from which crop roots extract water, typically 0–60cm.
- **Field Capacity:** Maximum soil water content after excess has drained.
- **Wilting Point:** Minimum soil moisture required to prevent plant wilting.
- **Available Soil Moisture:** Difference between field capacity and wilting point, important for scheduling irrigation[11].

Infiltration

- **Infiltration Rate:** Speed at which water enters soil; affects percolation, runoff, groundwater recharge, and frequency of irrigation.
- **Factors:** Soil texture, structure, compaction, organic matter, and moisture content.

7. Consumptive Use and Irrigation Requirement

- **Consumptive Use (CU):** Total water lost via evaporation + transpiration by a crop from planting to harvest.
- **Irrigation Requirement (IR):** Net water needed from irrigation to supplement effective rainfall.

$$\text{IR} = \text{Consumptive Use} - \text{Effective Rainfall}$$

Frequency of Irrigation

- Determined by:
  - Crop type and stage, soil water-holding capacity, climatic conditions, and irrigation method.
- Common intervals: 7–15 days for many crops when traditional surface methods are used[7].

8. Methods of Water Application

Method	Description	Advantages	Limitations
Surface Irrigation	Water flows over and across the field (furrow, basin, border)	Simple, low cost	Losses via runoff & deep percolation
Sub-surface	Water applied below the soil surface (via pipes or trenches)	Minimal evaporation loss	Installation cost, not suitable for all soils/crops[12]
Sprinkler	Water sprayed over crops like rainfall using pipes & pumps	Suitable for undulating land, uniform application	Higher energy cost, wind drift[13]
Drip/Trickle	Delivers water directly to root zone via emitters	High efficiency, reduced evaporation, water-saving	High initial cost, maintenance[13] [12]

- **Choice of method** depends on crop, soil, land shape, water quality, and economic factors.

Summary Table: Key Irrigation Concepts

Concept	Description/Importance
Water Withdrawals	Primarily for agriculture, energy, and flood control
Water for Agriculture	Dominant user (70% globally), vital for food security
Surface Water Supply	Analysis involves hydrology, demand forecasting, reservoir operations
Crop Patterns	Shaped by monsoon timing, water availability, economic priorities
Duty & Delta	Indicate efficient use of irrigation water
Water Quality	Salinity, sodicity, and ions impact crop yield and soil health
Soil-Water Relations	Root zone moisture, infiltration, and soil type affect irrigation needs
Irrigation Methods	Choice depends on water, crop, soil, and cost; includes surface, subsurface, sprinkler, and drip systems

An integrated understanding of water withdrawals, crop requirements, soil-water interactions, and irrigation practices is essential for ensuring food security, optimizing water use efficiency, and sustaining agricultural productivity under variable environmental and resource conditions. [3] [4] [8] [10] [11] [13] [7] [9] [12]

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1. https://www.planete-energies.com/en/media/article/energy-and-water-are-closely-intertwined
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