清華大學
Tsinghua University

FIPSE (ΦΨ) - 4

Information-decision support systems for intelligent irrigation

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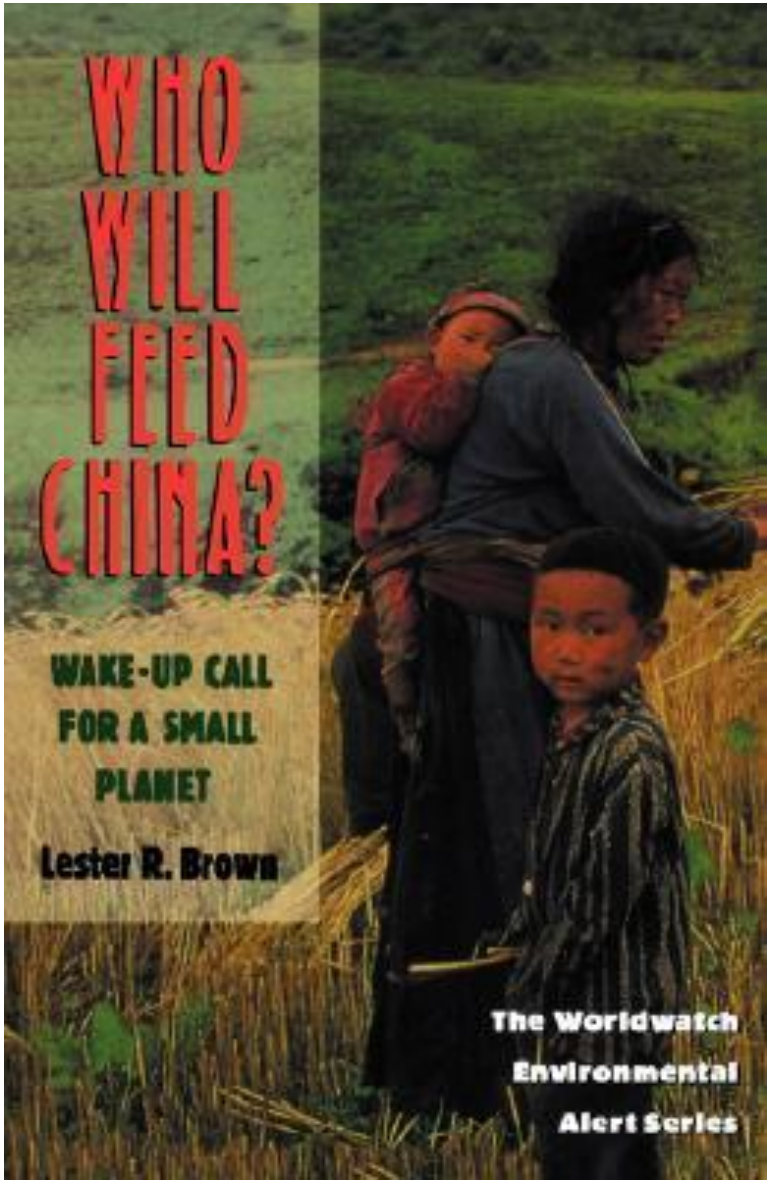
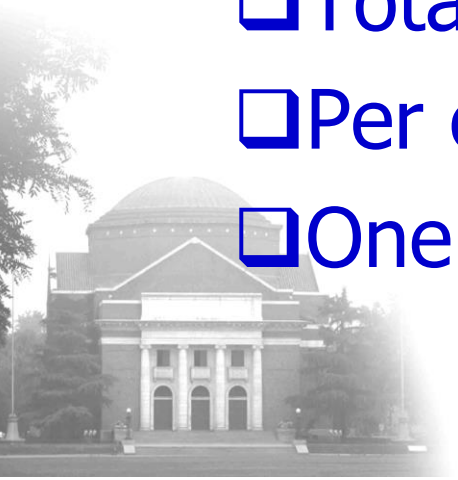
Can China feed itself?

- World's largest developing country
- Agricultural country to industrialized / modernized country



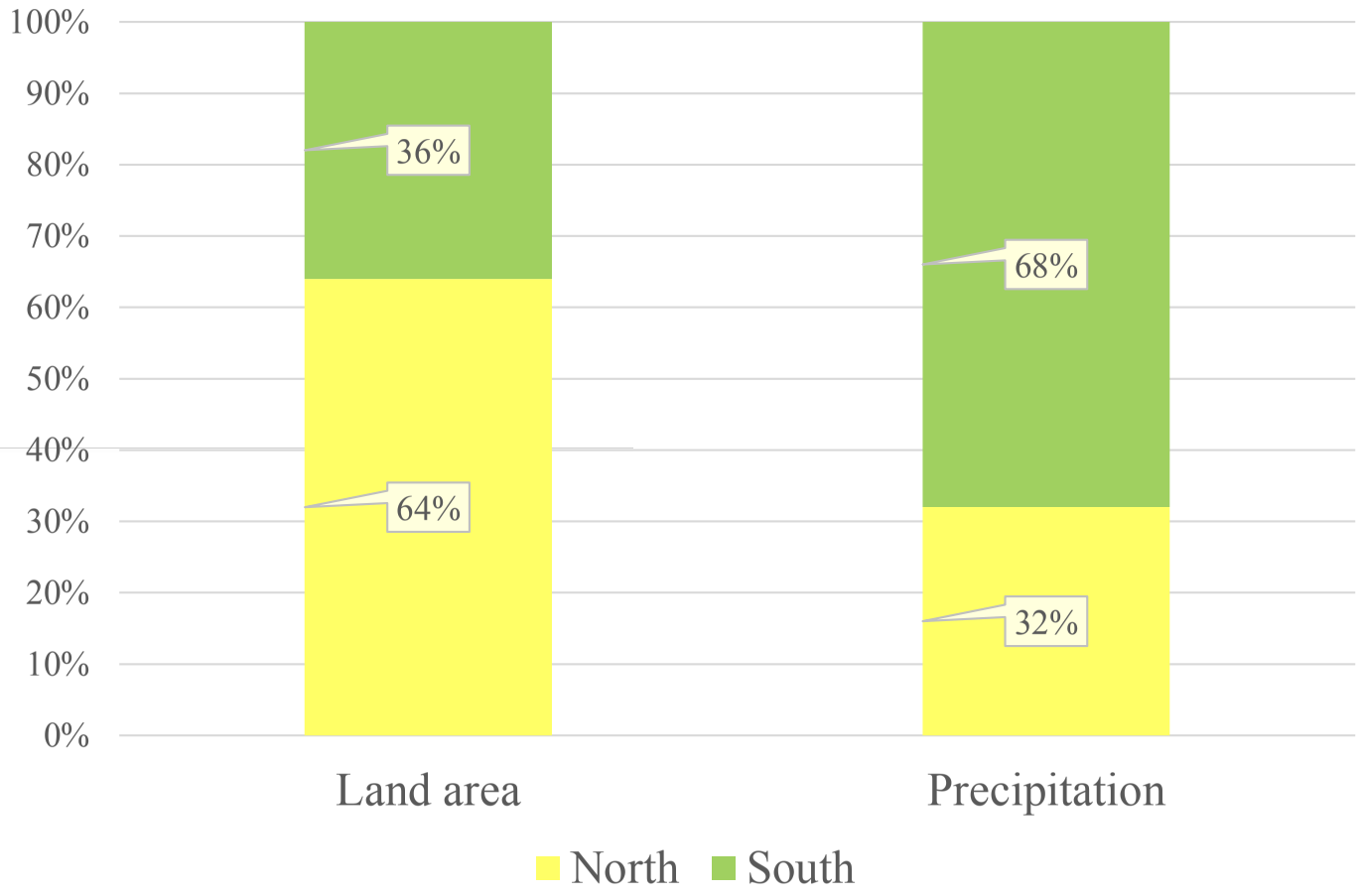
China

- Population: 1.4 billion, ~1/5 of the world population
- Arable land area:
  - Total: <10% of the world
  - Per capita: <1/2 of the world average
- Water resources:
  - Total: rank 5/6th in the world
  - Per capita: 28% of the world average
  - One of the water-deficient countries

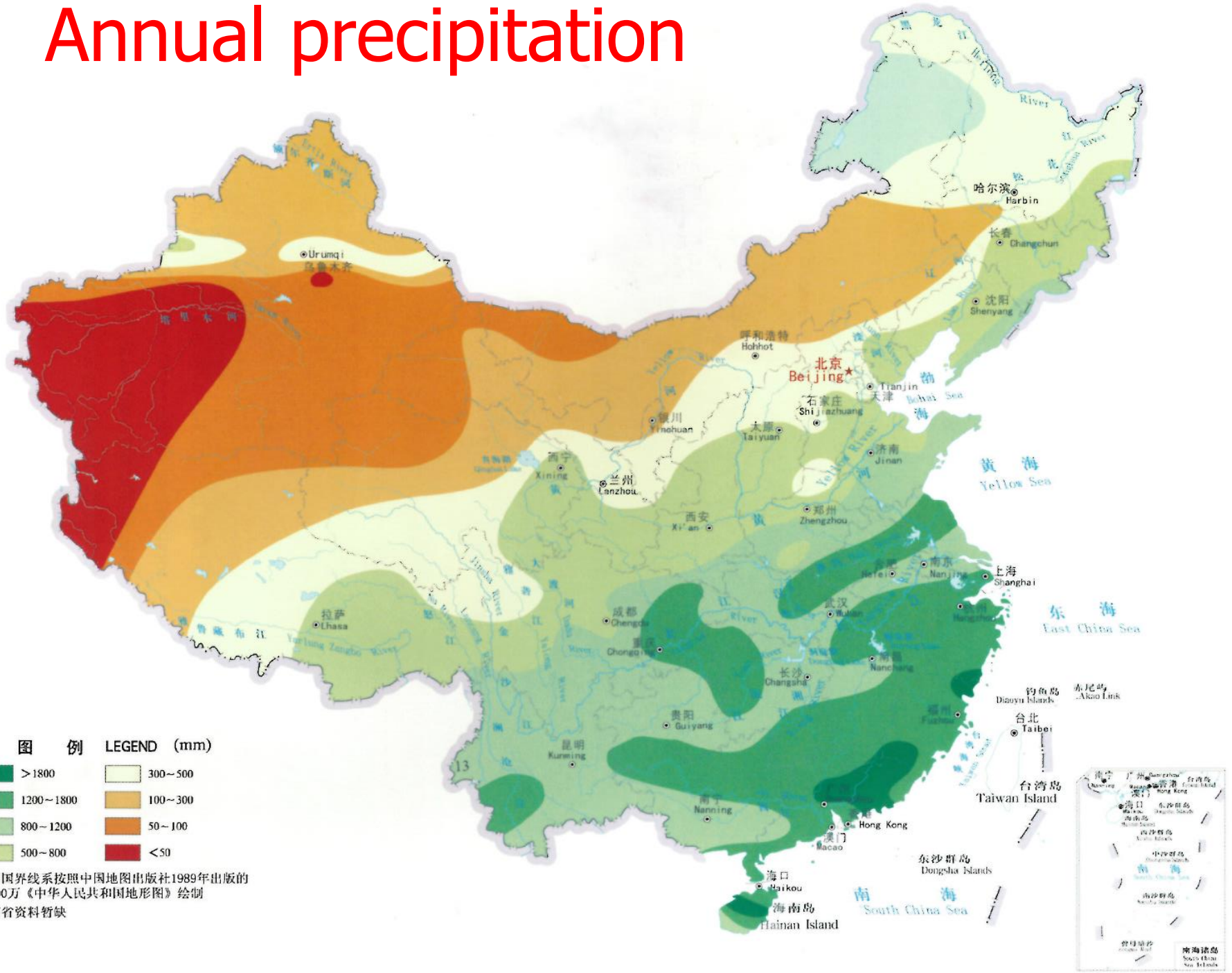


Imbalance

❖Precipitation

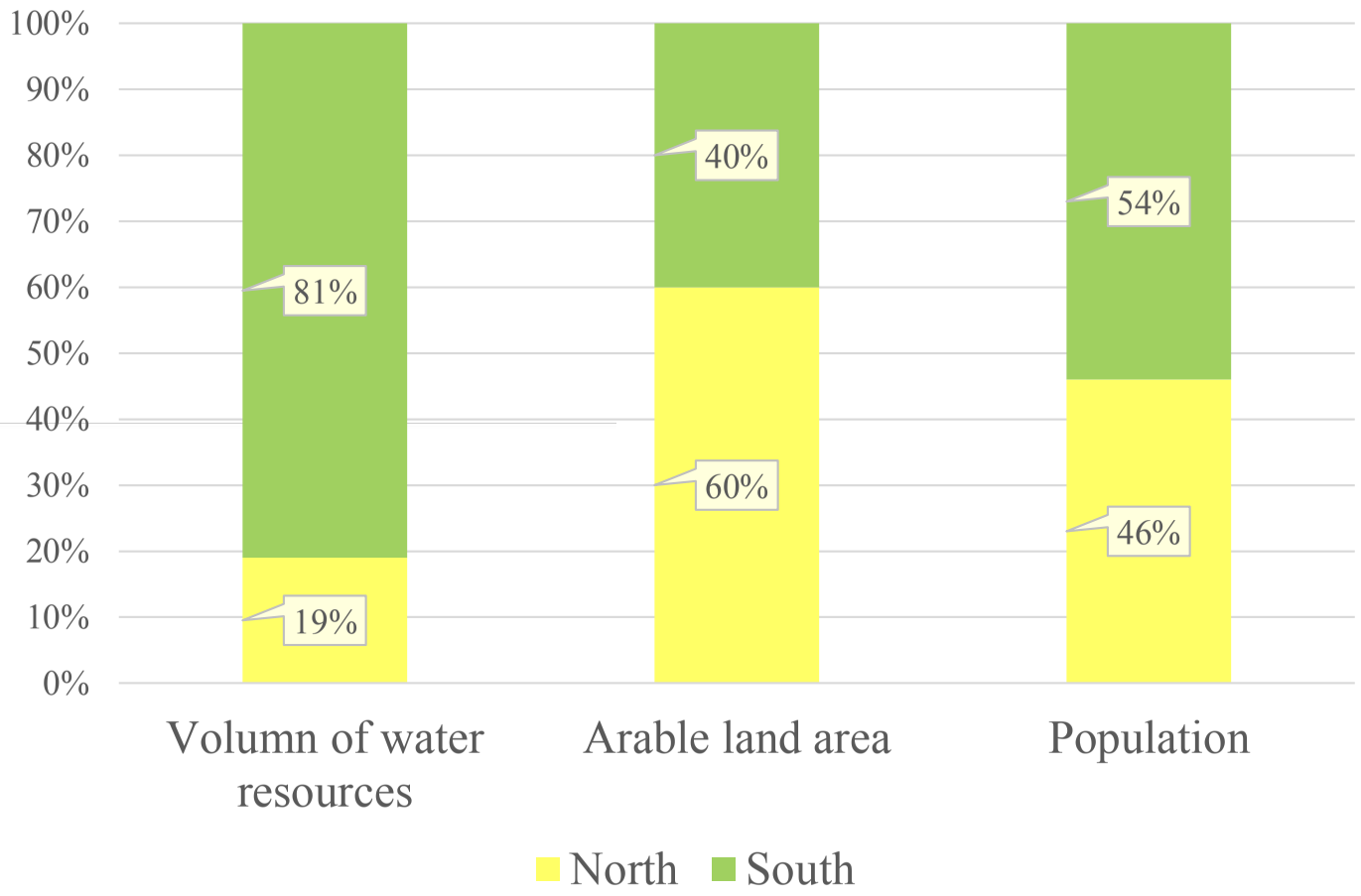


Annual precipitation

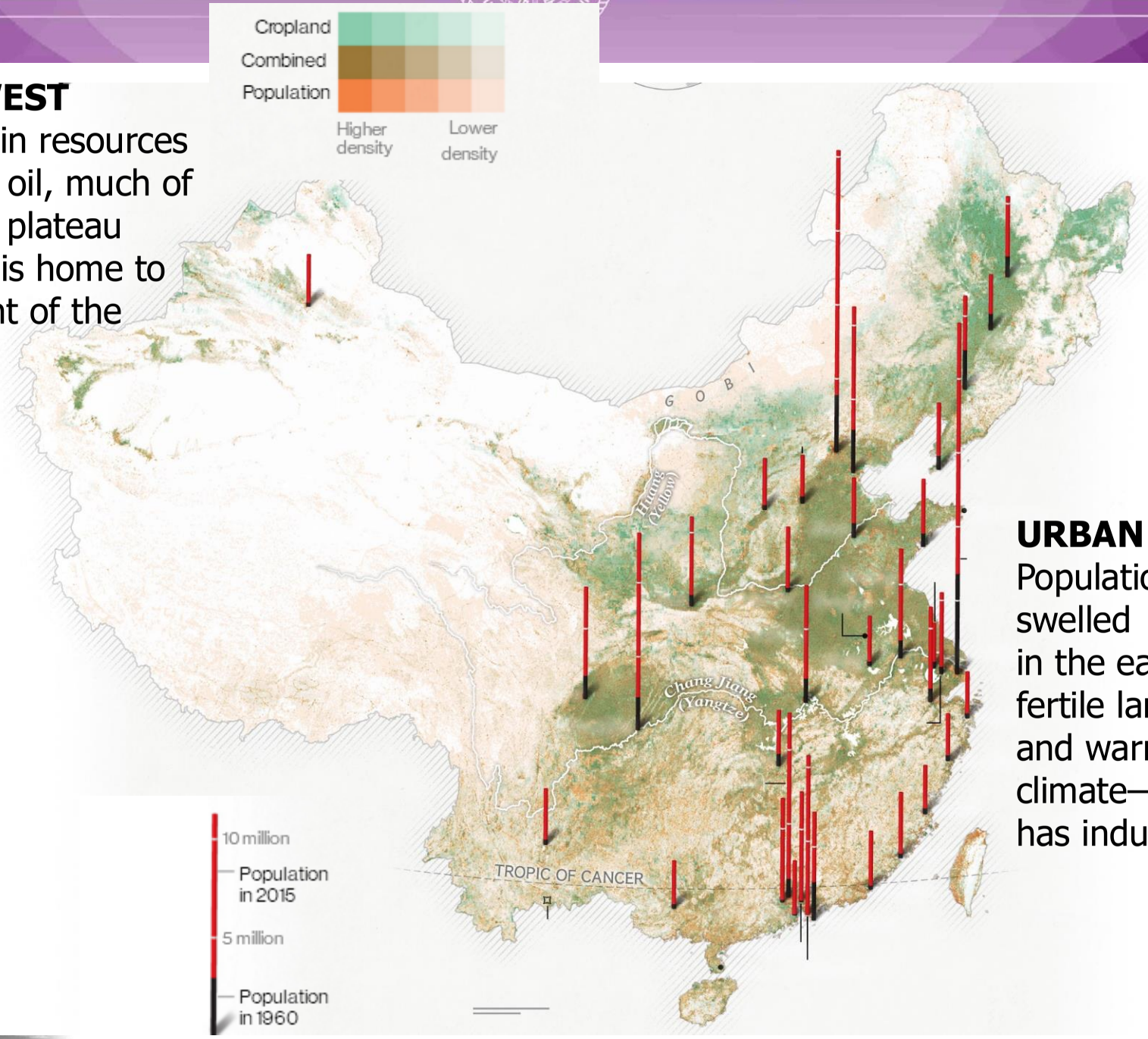


Imbalance

❖Water resources



RUGGED WEST
Though rich in resources like coal and oil, much of the region is plateau or desert. It is home to just 6 percent of the population.



URBAN EAST
Populations have swelled in the east—with its fertile land and warmer climate—as China has industrialized

Small fragmented nature of Chinese farms

Compared to big areas by center-pivot irrigation

Food security!!!

- Broaden the sources of income and reduce expenditure
  - Hydraulic engineering
  - Water-saving strategy

Water diversion: South-North Water Transfer Project

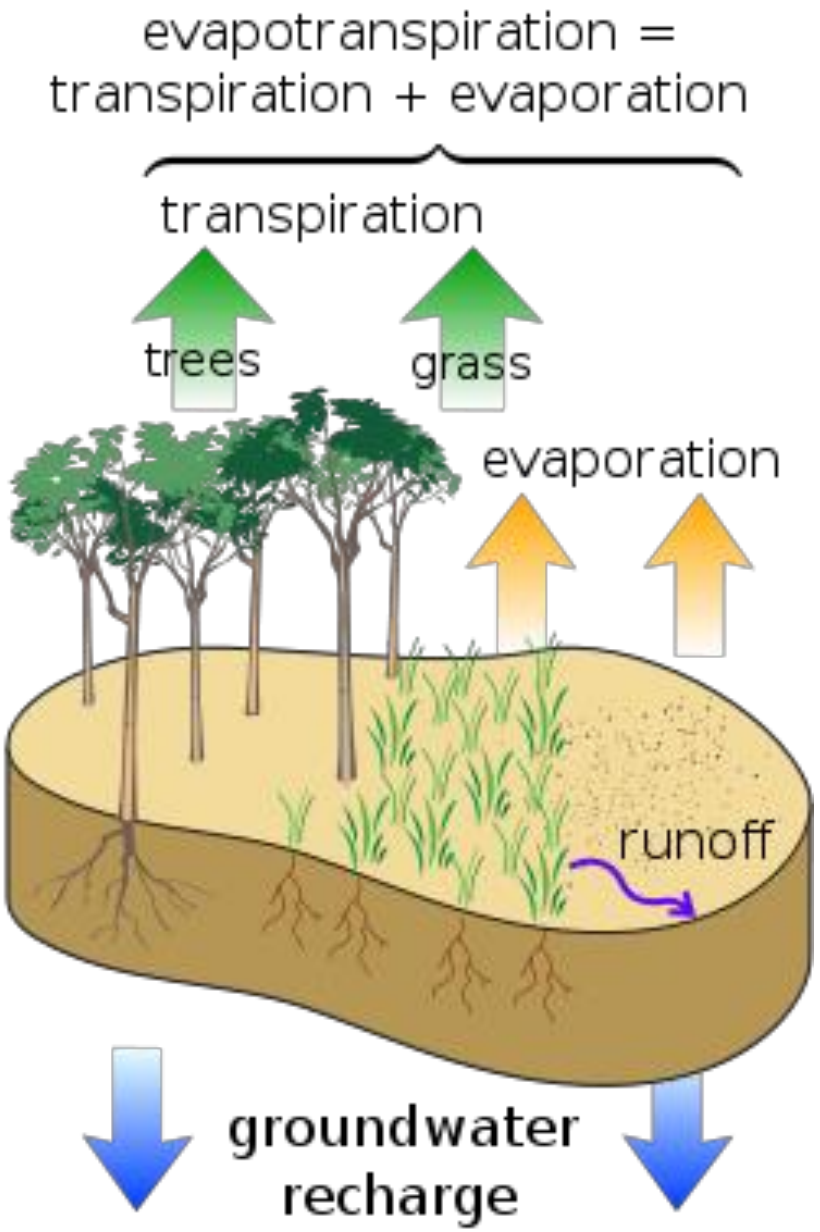
Water diversion: "Hongqi River" Project

Water use

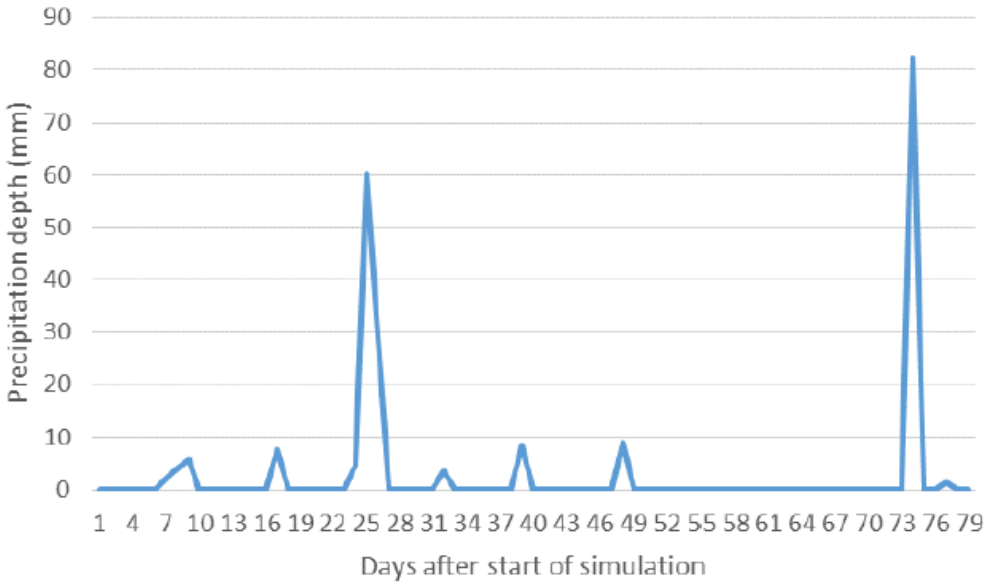
- >70% of fresh water used in agriculture
- Majority is used for irrigation
- Water use coefficient is only ~0.5
  - Too much waste!!!

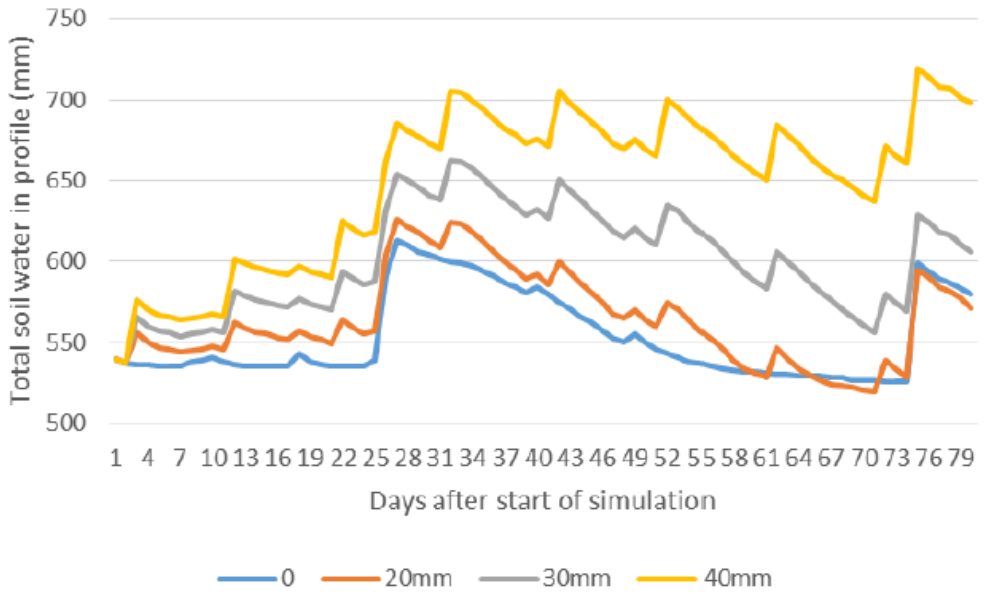
Demand for irrigation water

- Evapotranspiration (ET)
- Demand for irrigation water = ET – precipitation



Precipitation – total soil water – yield





Best

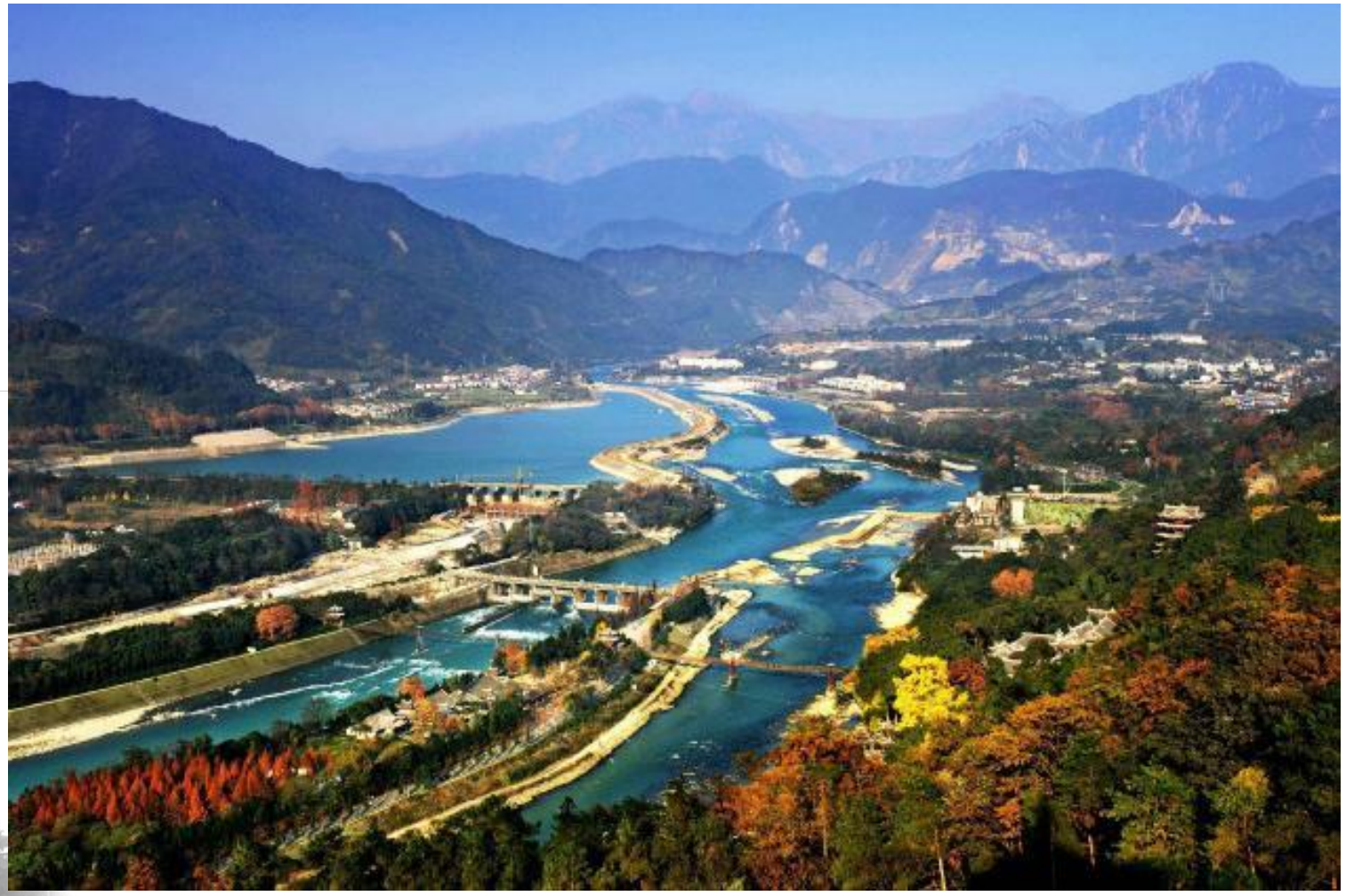
Irrigation Plan (mm/10days)	0	20	30	40
Yield (kg/ha)	2262	6257	6880	6305

Irrigation for agriculture in China

- Irrigation area: ~66 million hectares = ~1/2 of area of arable land
- <1/2 is conducting water-saving irrigation

Irrigation in ancient China

Dujiangyan (~ 256 BC): Irrigation and flood control project



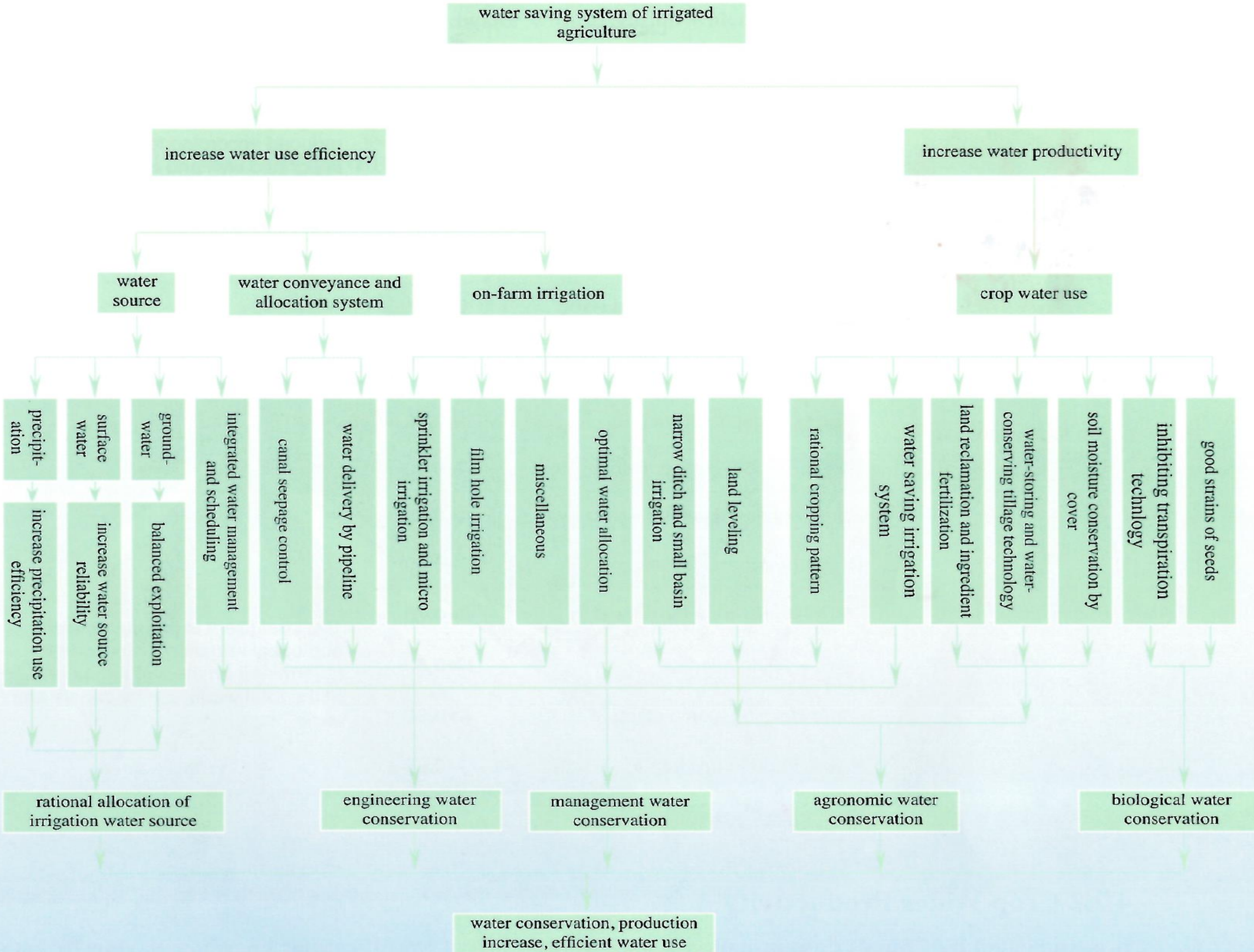
Irrigation in ancient China

Droughts and floods now and then

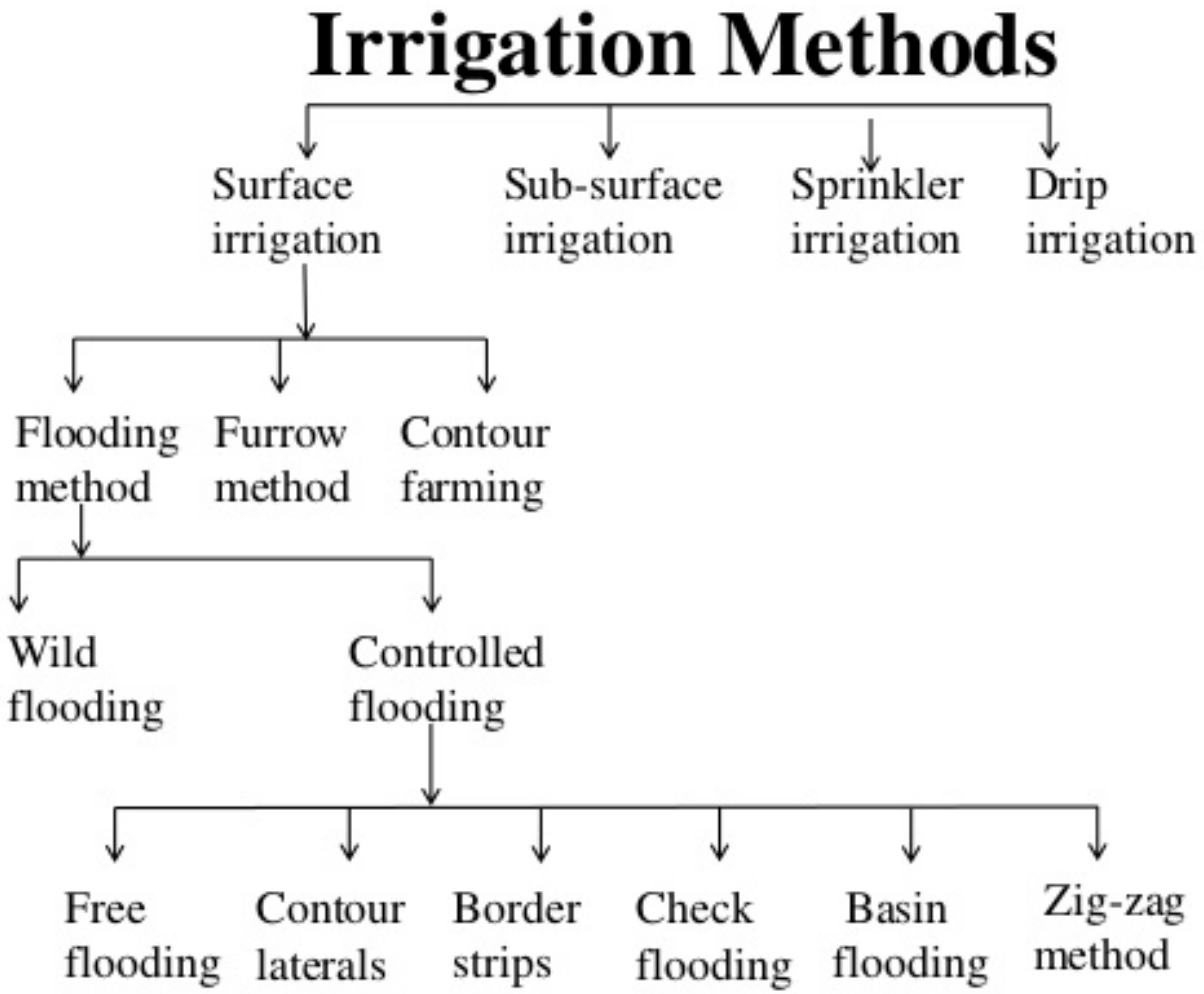
- Lags behind in modern times
- Have to learn from others
- Water use coefficient can be >0.8

The 13th Five-Year Plan (2016-2020)

- Water-efficient agriculture
  - Accelerate the implementation of regional scaled high-efficiency water-saving irrigation projects, using water-conserving methods to increase crop production in the northeast, raise irrigation efficiency in the northwest, address groundwater overdraft in the north, and reduce waste water discharge in the south.
  - Increase the area of cropland making use of high-efficiency water-conserving irrigation by 6.7 million hectares, thereby raising the irrigation water utilization coefficient to 0.55 or above.


water saving system of irrigated agriculture
increase water use efficiency
increase water productivity
water source
water conveyance and allocation system
on-farm irrigation
crop water use
precipit-ation
surface water
ground-water
integrated water management and scheduling
canal seepage control
water delivery by pipeline
sprinkler irrigation and micro irrigation
film hole irrigation
miscellaneous
optimal water allocation
narrow ditch and small basin irrigation
land leveling
rational cropping pattern
water saving irrigation system
land reclamation and ingredient fertilization
water-storing and water-conserving tillage technology
soil moisture conservation by cover
inhibiting transpiration technology
good strains of seeds
increase precipitation use efficiency
increase water source reliability
balanced exploitation
rational allocation of irrigation water source
engineering water conservation
management water conservation
agronomic water conservation
biological water conservation
water conservation, production increase, efficient water use

Irrigation methods



Surface irrigation

Flood irrigation

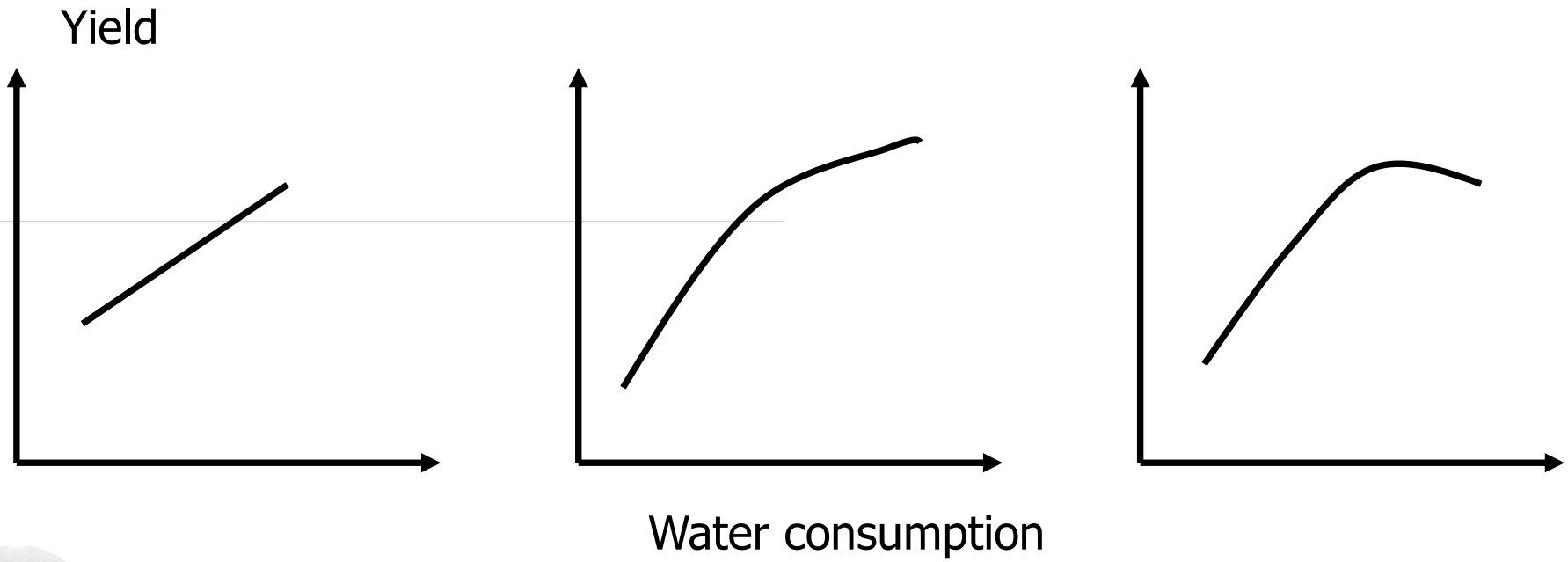
Furrow irrigation

Sprinkler irrigation

Drip irrigation

Irrigation management

- Limited irrigation
  - Relationship between yield and water supply is not linear, or even monotone



  - unit yield ↓ , irrigation area ↑

Optimization

Irrigation management

- RDI (Regulated deficit irrigation): to maximize crop water productivity (kg/m³) instead of maximizing the harvest per unit land

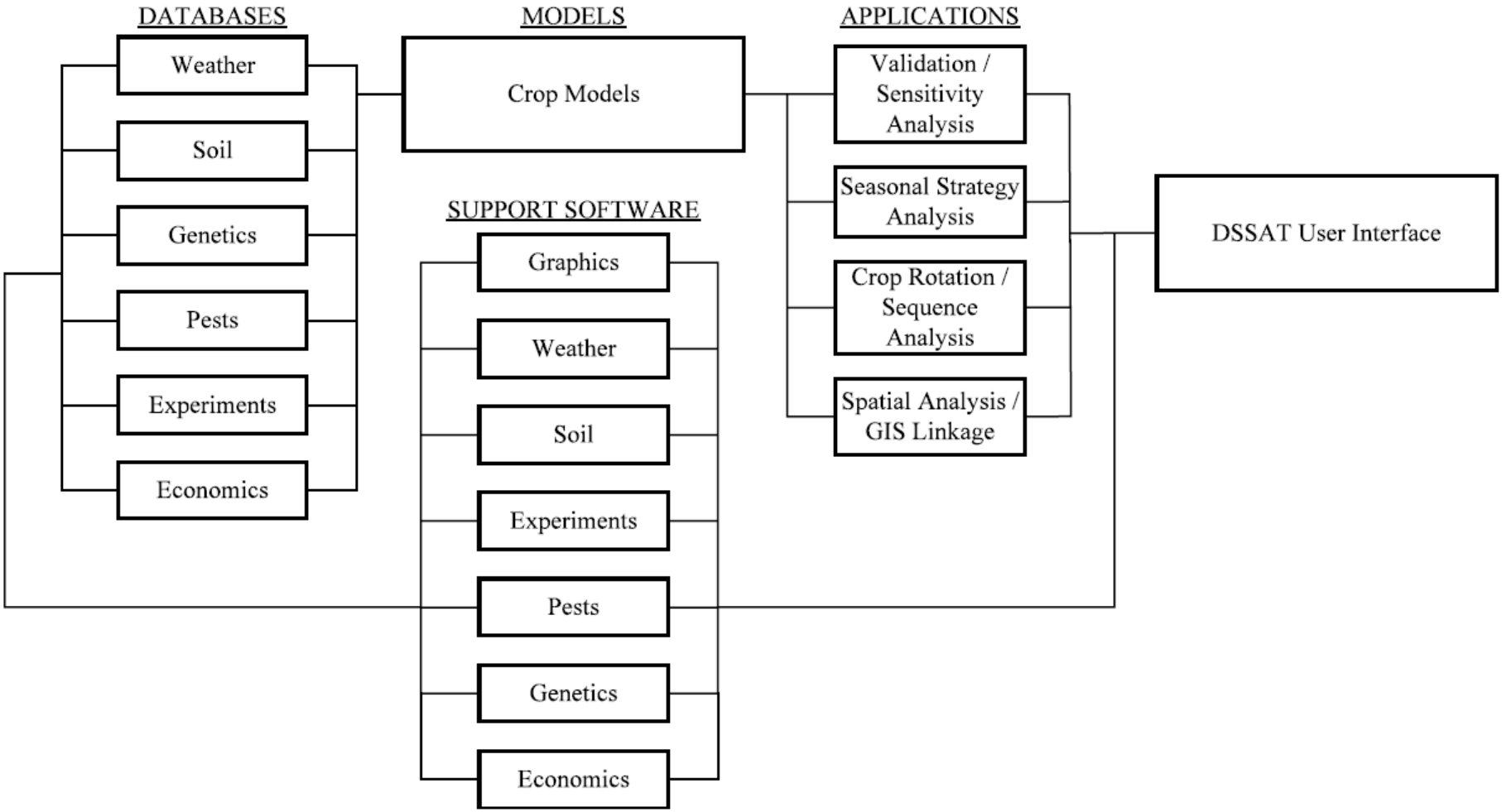
Optimization

- Advantages
  - Maximizes the productivity of water, generally with adequate harvest quality
  - Allows economic planning and stable income due to a stabilization of the harvest in comparison with rainfed cultivation
  - Decreases the risk of certain diseases linked to high humidity (e.g. fungi) in comparison with full irrigation
  - Reduces nutrient loss by leaching of the root zone, which results in better groundwater quality and lower fertilizer needs
  - Improves control over the sowing date and length of the growing period independent from the onset of the rainy season and therefore improves agricultural planning
- Constraints
  - Exact knowledge of the crop response to water stress
  - Sufficient flexibility in access to water during periods of high demand (drought sensitive stages of a crop)
  - A minimum quantity of water for the crop
  - The risk for soil salinization is higher as compared to full irrigation

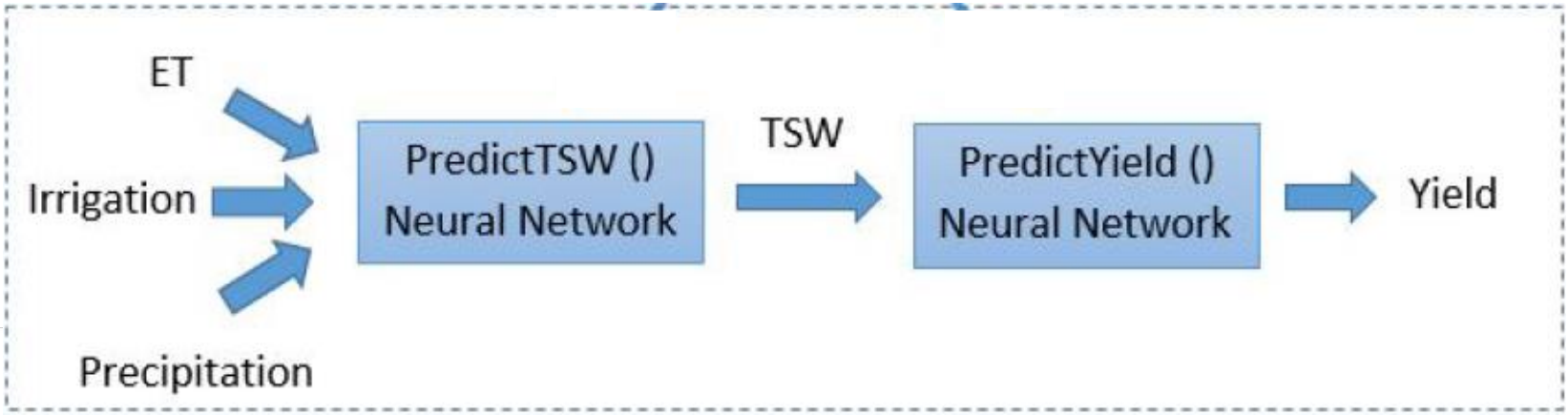
Modeling

- Modeling and simulation of the soil water balance and related crop growth (crop water productivity modeling)
- Influencing factors: climate, soil, management, crop characteristics
- With the models, one can
  - better understand the mechanism behind improved water use efficiency
  - schedule the necessary irrigation applications during the drought sensitive crop growth stages, considering the possible variability in climate
  - test RDI strategies of specific crops in new regions
  - investigate the effects of future climate scenarios or scenarios of altered management practices on crop production

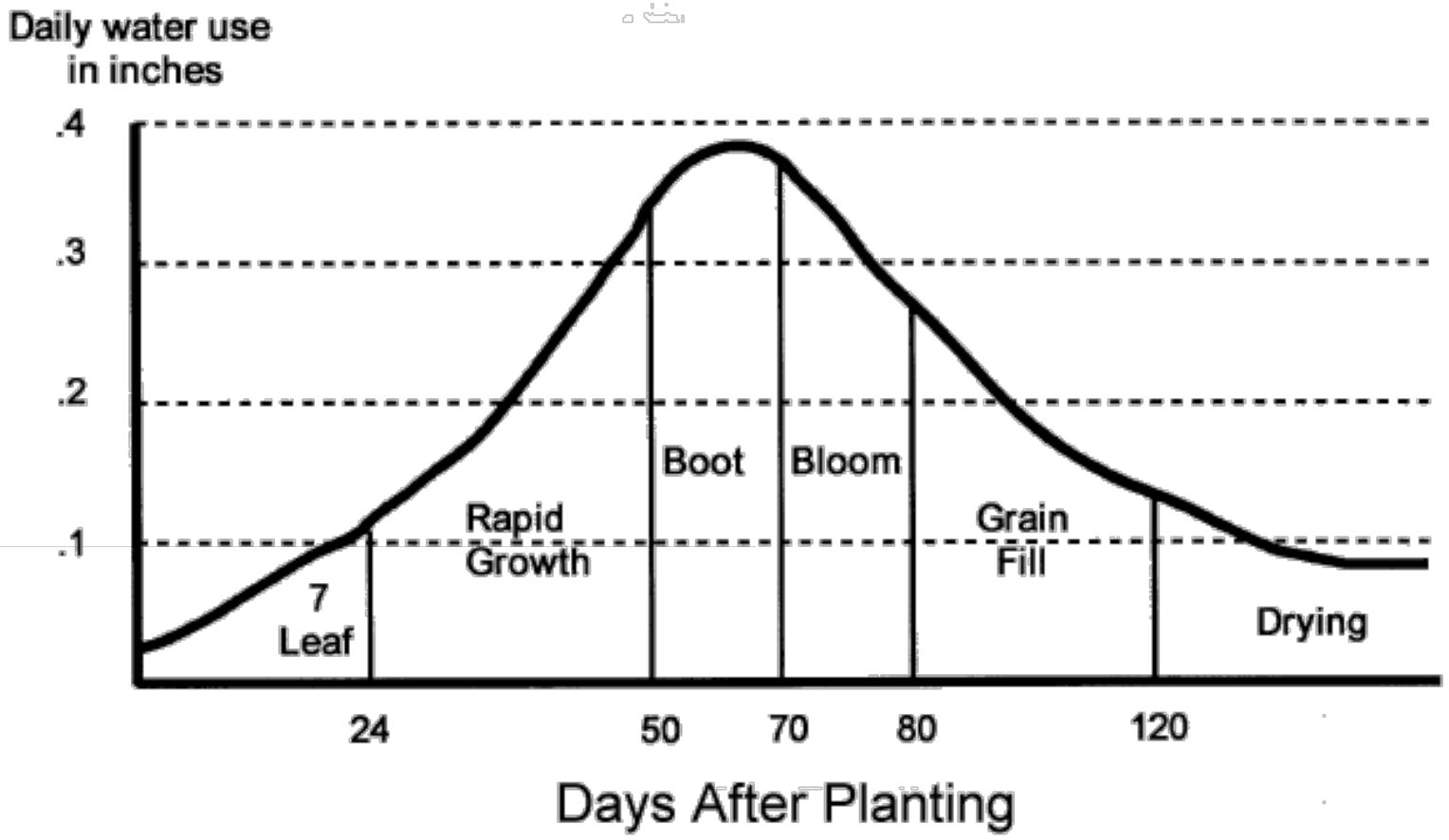
The DSSAT cropping system model



Neural network modeling



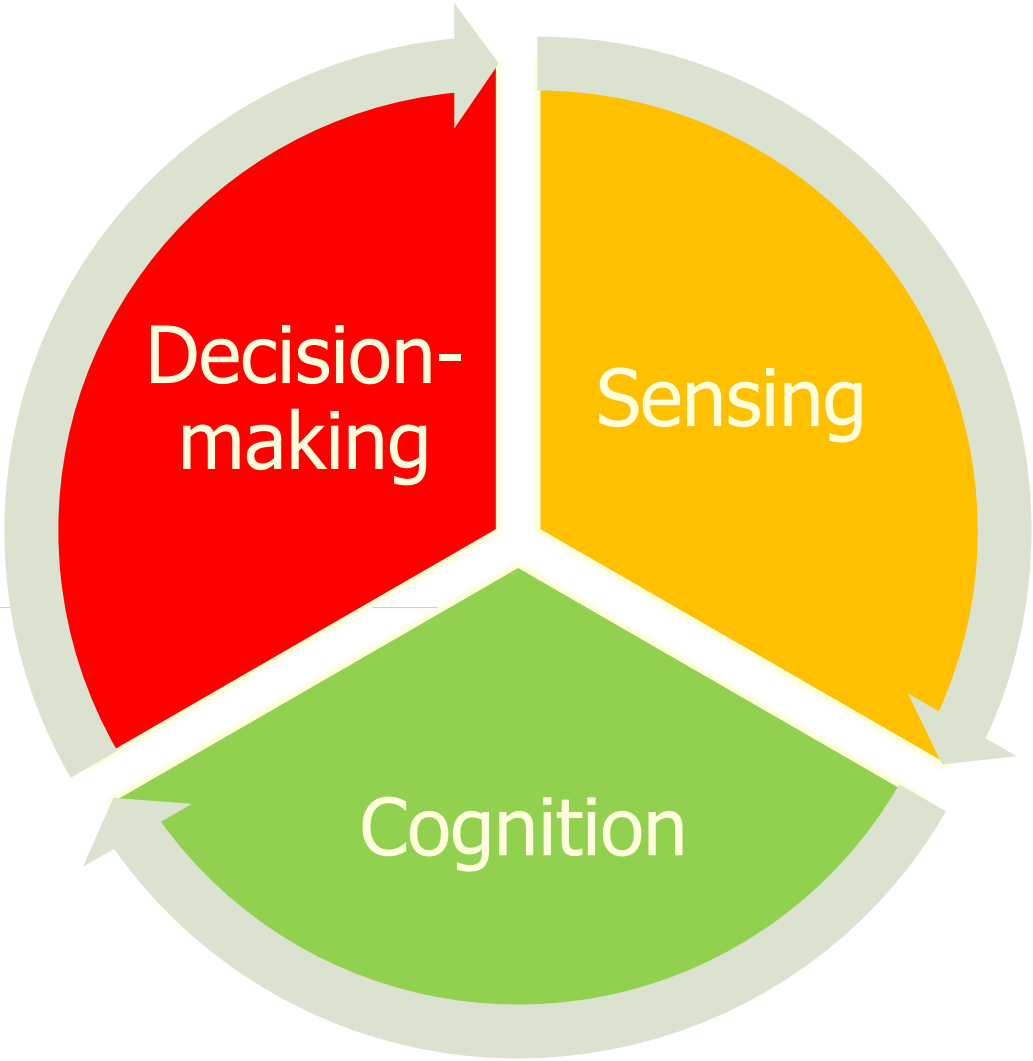
Water consumption in different stages



Scheduling

- Open problem:
  - strategy of RDI to improve water productivity
  - Modeling? Control? Optimization?

Incorporation of artificial intelligence



from big data to knowledge, and from knowledge to decision-making

What makes agriculture different?

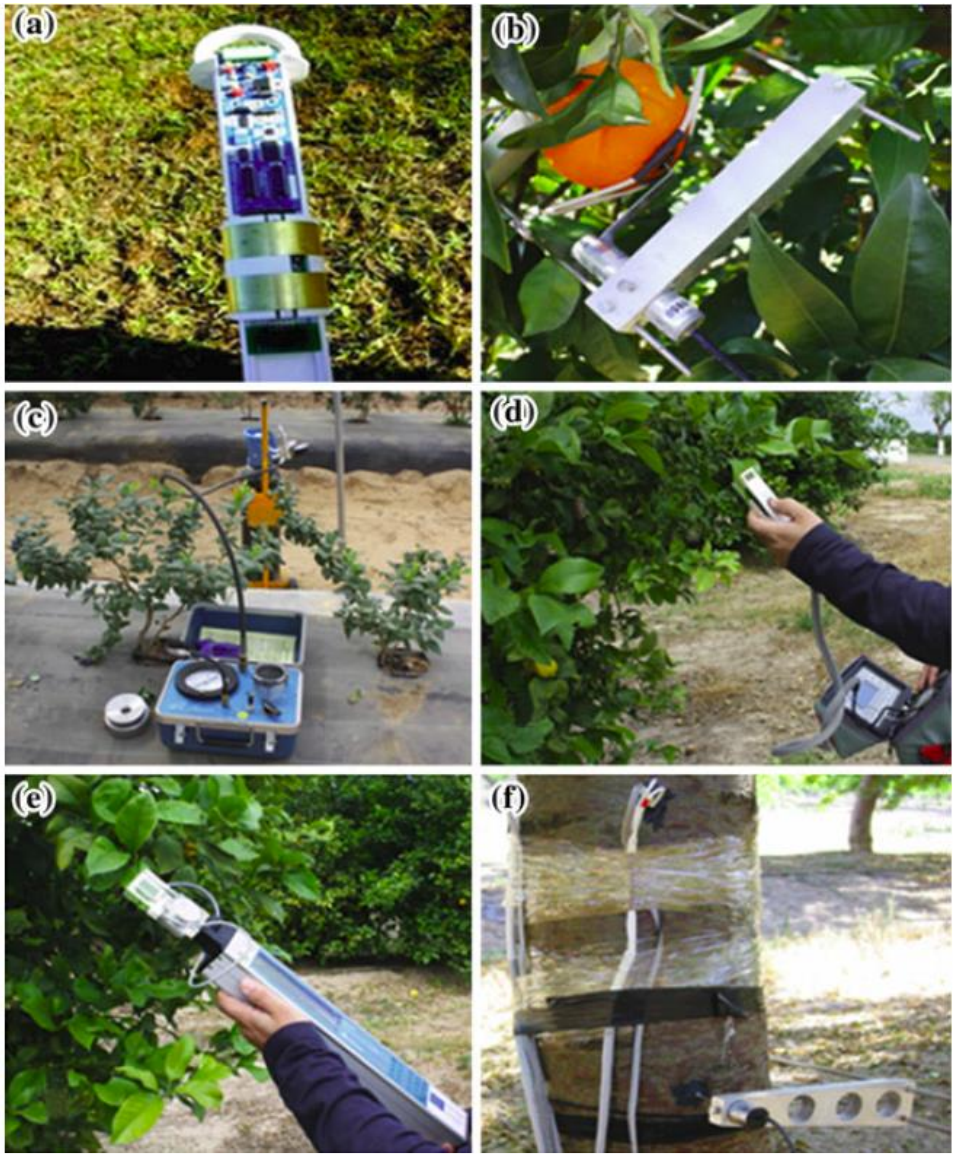
- Conditions are always changing from one section to another – distributed
- Unpredictable weather, changes in soil quality, pests and disease – uncertainty
- No two environments will be exactly alike – adaptability

To "algorithm" agriculture

Precision agriculture

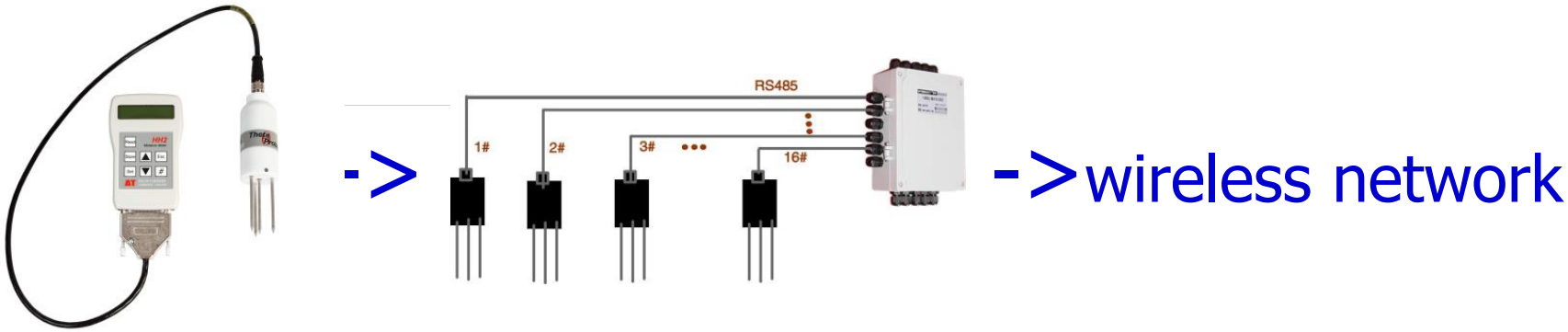
Sensing

- Measurement of soil moisture content
  - TDR (Time Domain Reflector), FDR (Frequency Domain Reflectometry)
  - Devices:
    - Multi sensor capacitance probes (FDR) (a), dendrometer for fruit diameter (b), plant water potential (c), porometer for stomatal conductance (d), device for leaf photosynthetic activity (e), and sap flow and dendrometer for trunk fluctuations (f)



Sensing

- Measurement of soil moisture content
  - TDR (Time Domain Reflector), FDR (Frequency Domain Reflectometry)
- Internet of things

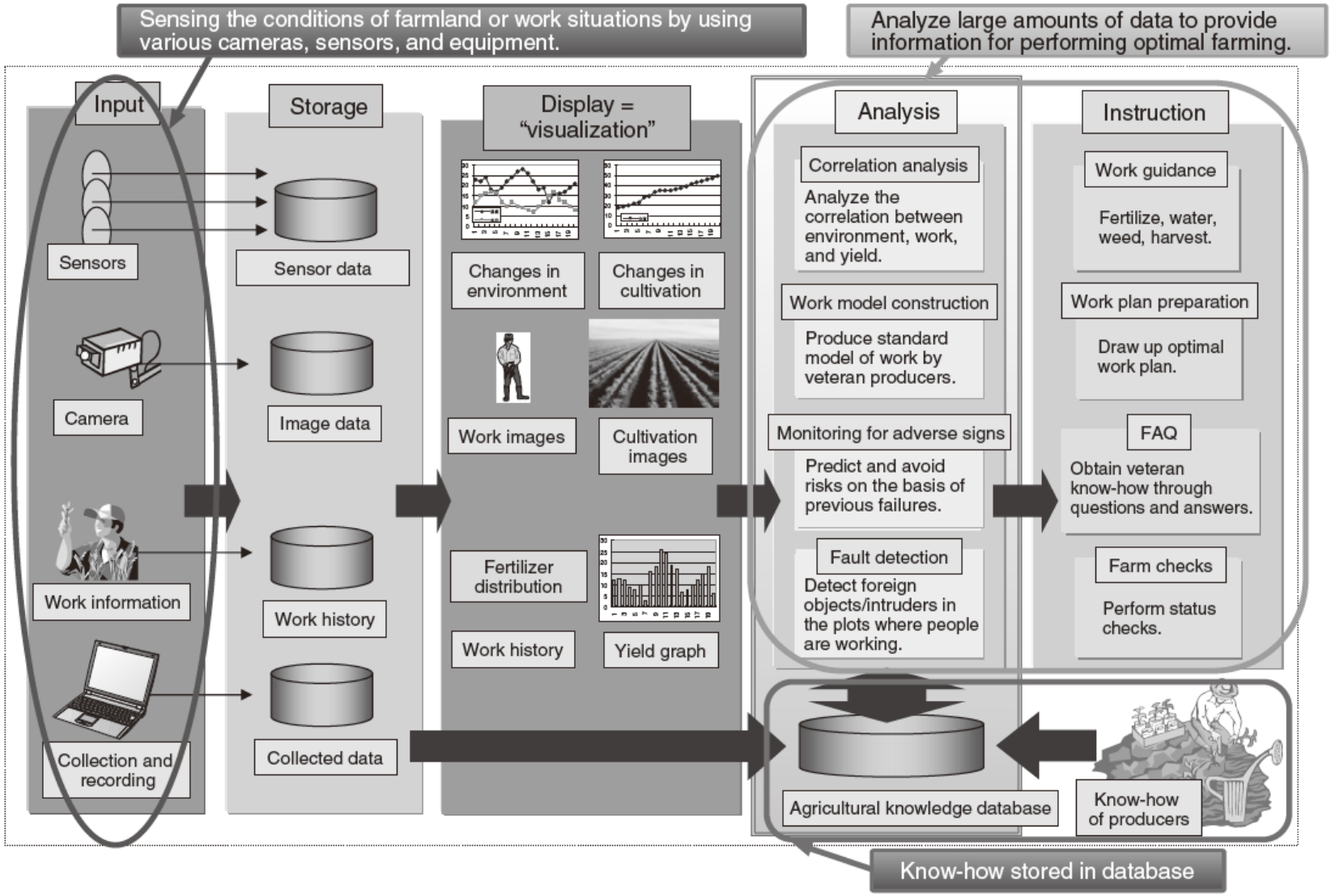


-> -> wireless network

- Application of UAVs

Cognition

- Data analytics: capture, curation, storage, search, sharing, transfer, analysis, and visualization



Cognition

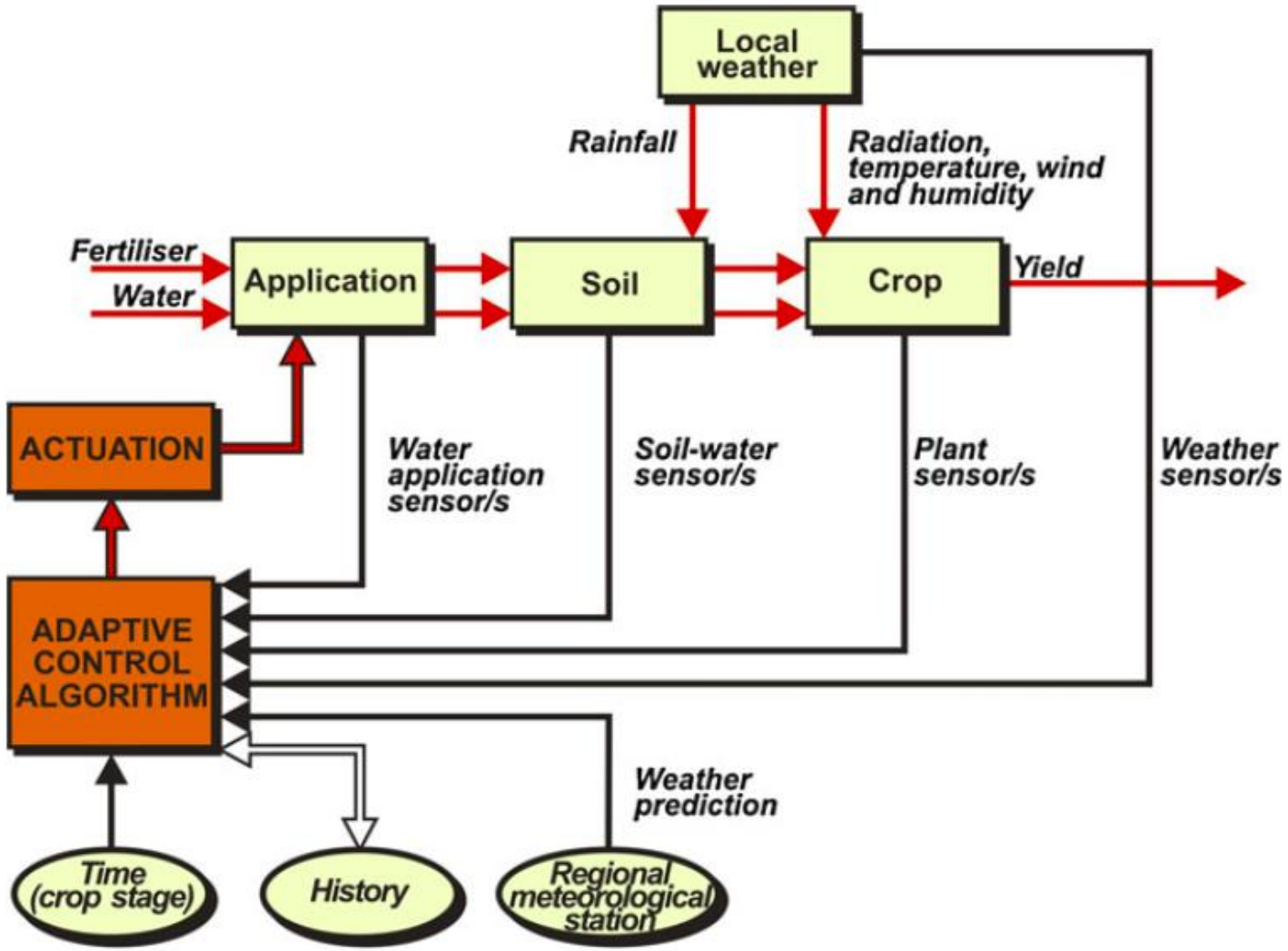
- Situation awareness
- Soil moisture content monitoring
- Prediction of ET and precipitation
- Knowledge extraction from historians and work logs
- Cloud computing techniques

Decision-making

- Integrated management of water and fertilizer
- Reinforcement learning and control for decision making and optimization of water-saving irrigation
- Assessment of treatments
- Incorporation of market data

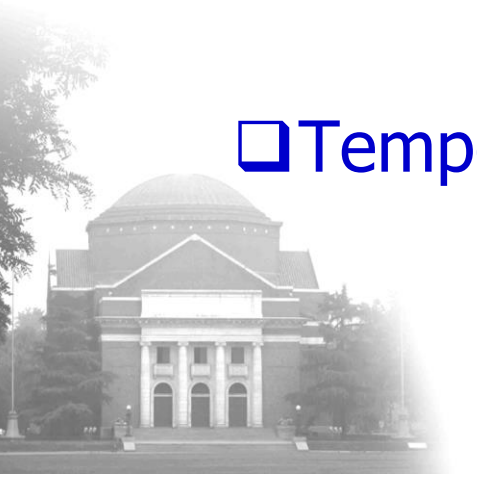
Irrigation control

- Advanced process control: MPC

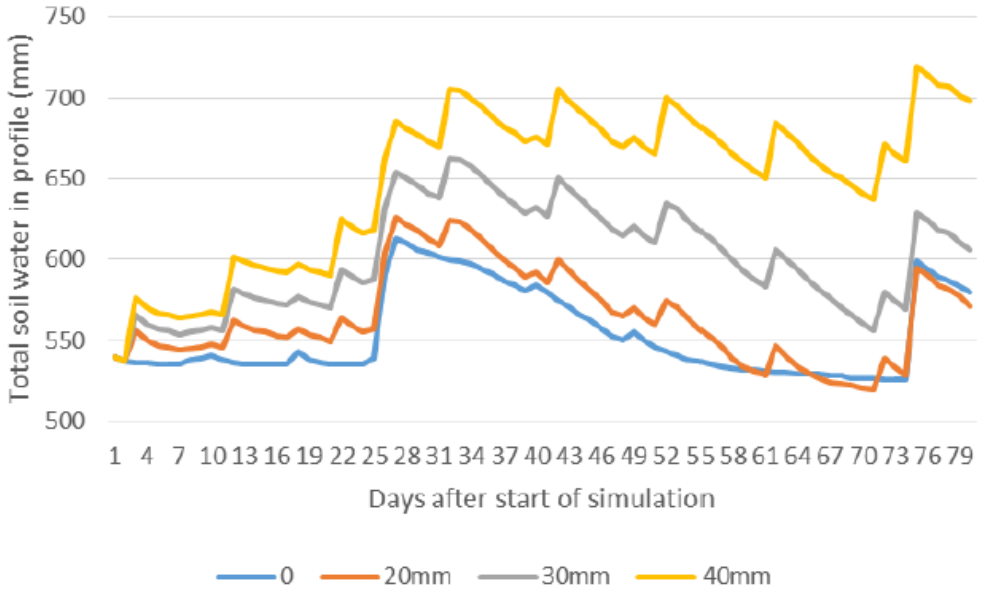


Irrigation control

- Model-free reinforcement learning control
  - Markov decision process
  - Crops growth process: a Markov chain
  - States: $S=\{s_1, s_2, \ldots\}$
  - Actions: $A=\{a_1, a_2, \ldots\}$
  - Reward: $r\ (s_i, a_j)$
  - Policy
  - NetReturn = crop yield * product price
    – water use * water price
  - Temporal difference learning algorithm SARSA(λ)



- Amount of water irrigated every time
  - Fixed
  - To target filling point
  - Any amount?



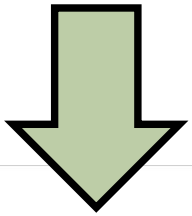
Next Generation AI

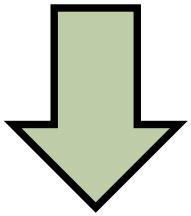
- A Next Generation Artificial Intelligence Development Plan, Released 2017

Smart agriculture. Research and formulate smart agricultural sensing and control systems, smart agricultural equipment, autonomous tasking systems for farming equipment across fields, etc. Establish and complete smart agriculture information remote sensing and monitoring networks integrating air, space, and land components. Establish agriculture big data smart decision-making and analysis systems, launch trials of smart farms, smart plant factories, smart pastures, smart fisheries, smart orchards, smart farm produce processing workshops, green and smart farm product supply chains and other such integrated applications.

Agriculture informationization

Automatic irrigation





Intelligent irrigation

Open questions

- For smart or precision agriculture, in particular irrigation, how to extract knowledge for situation awareness by big data analytics?
- How to improve water productivity by optimization and scheduling in RDI (regulated deficit irrigation)?

References

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- Courtesy of material from internet

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Thank you for your attention!