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science for global insight

Optimal Resource Allocation (1)

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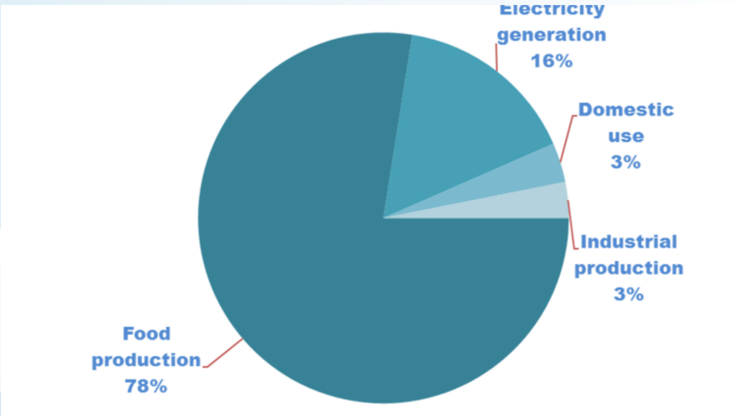
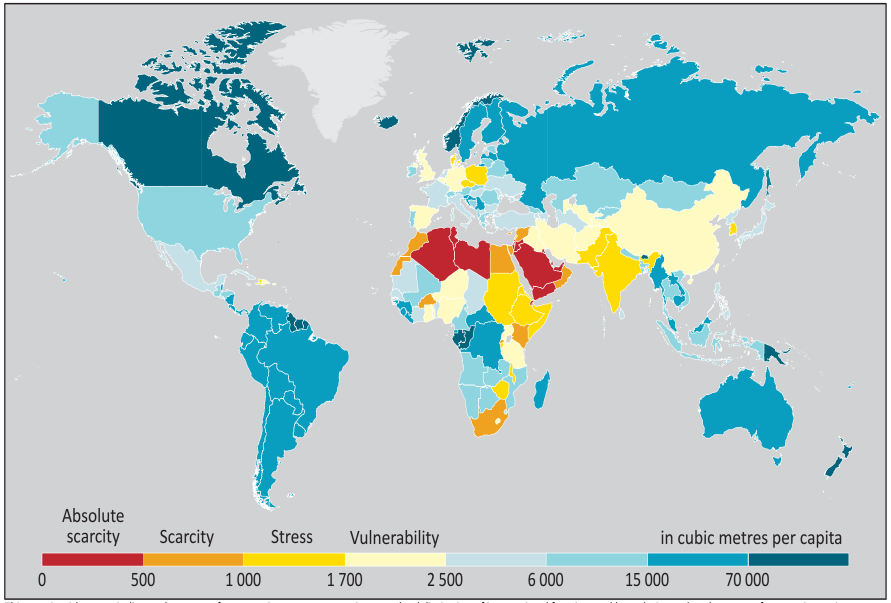
Part 1-1:
Food-water-energy nexus

Different sectors rely on water

Global water consumption



Source:
http://theconversation.com/energy-sector-is-one-of-the-largest-consumers-of-water-in-a-drought-threatened-world-59109

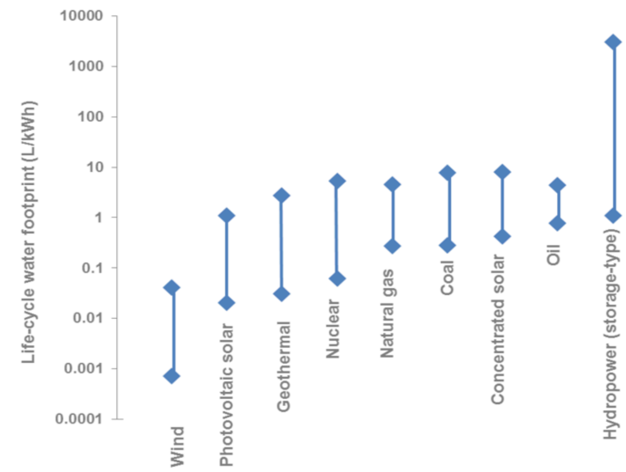


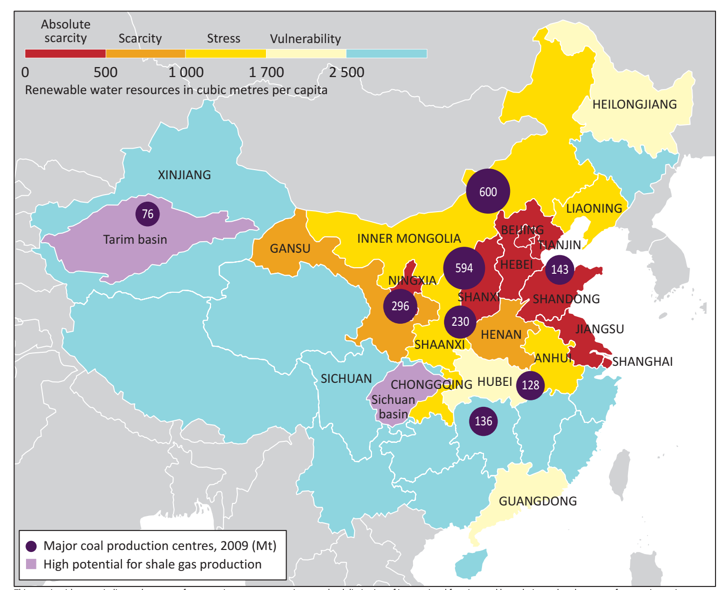
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: UN FAO Aquastat database.

Water requirements of energy sector

	Uses	Potential water quality impacts
Primary energy production		
Oil and gas	Drilling, well completion and hydraulic fracturing. Injection into the reservoir in secondary and enhanced oil recovery. Oil sands mining and in-situ recovery. Upgrading and refining into products.	Contamination by tailings seepage, fracturing fluids, flowback or produced water (surface and groundwater).
Coal	Cutting and dust suppression in mining and hauling. Washing to improve coal quality. Re-vegetation of surface mines. Long-distance transport via coal slurry.	Contamination by tailings seepage, mine drainage or produced water (surface and groundwater).
Biofuels	Irrigation for feedstock crop growth. Wet milling, washing and cooling in the fuel conversion process.	Contamination by runoff containing fertilisers, pesticides and sediments (surface and groundwater). Wastewater produced by refining.
Power generation		
Thermal (fossil fuel, nuclear and bioenergy)	Boiler feed, *i.e.* the water used to generate steam or hot water. Cooling for steam-condensing. Pollutant scrubbing using emissions-control equipment.	Thermal pollution by cooling water discharge (surface water). Impact on aquatic ecosystems. Air emissions that pollute water downwind (surface water). Discharge of boiler blowdown, *i.e.* boiler feed that contains suspended solids.
Concentrating solar power and geothermal	System fluids or boiler feed, *i.e.* the water used to generate steam or hot water. Cooling for steam-condensing.	Thermal pollution by cooling water discharge (surface water). Impact on aquatic ecosystems.
Hydropower	Electricity generation. Storage in a reservoir (for operating hydro-electric dams or energy storage).	Alteration of water temperatures, flow volume/timing and aquatic ecosystems. Evaporative losses from the reservoir.





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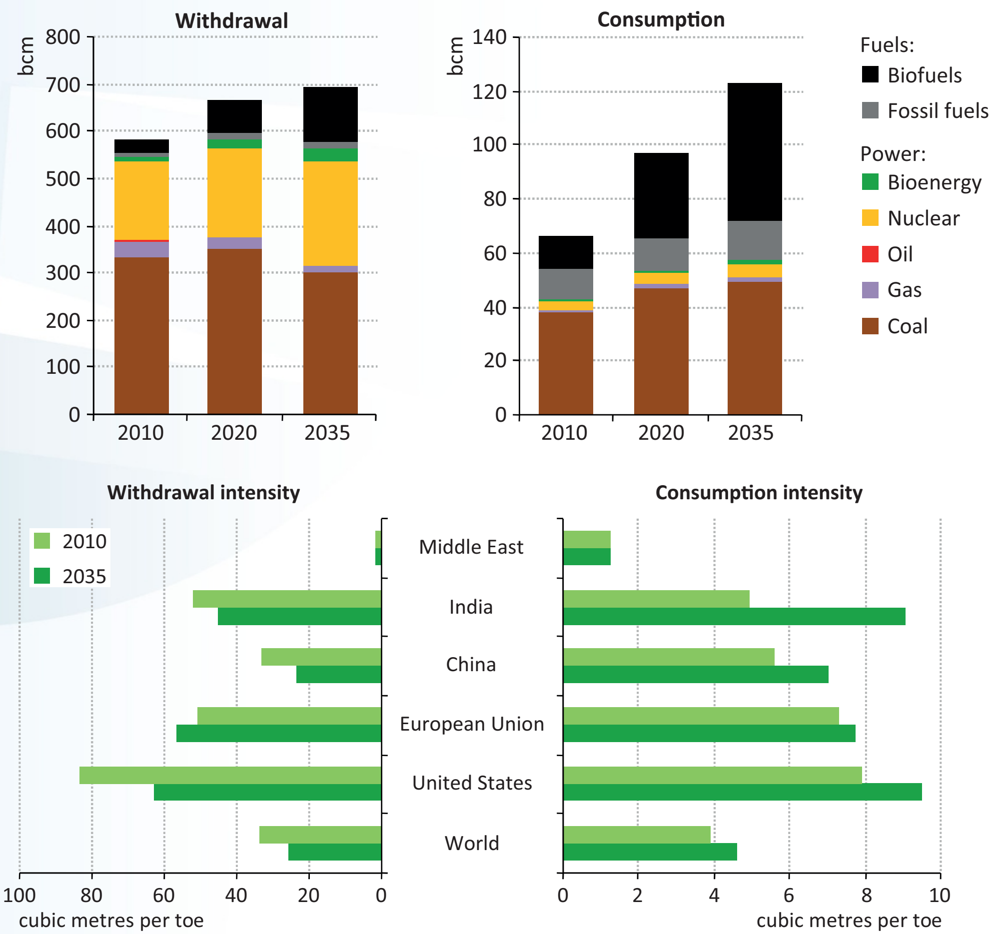
Source: Water for Energy, World Energy Outlook, IEA, 2012

Future trends

Under growing population and demand, water consumption increases



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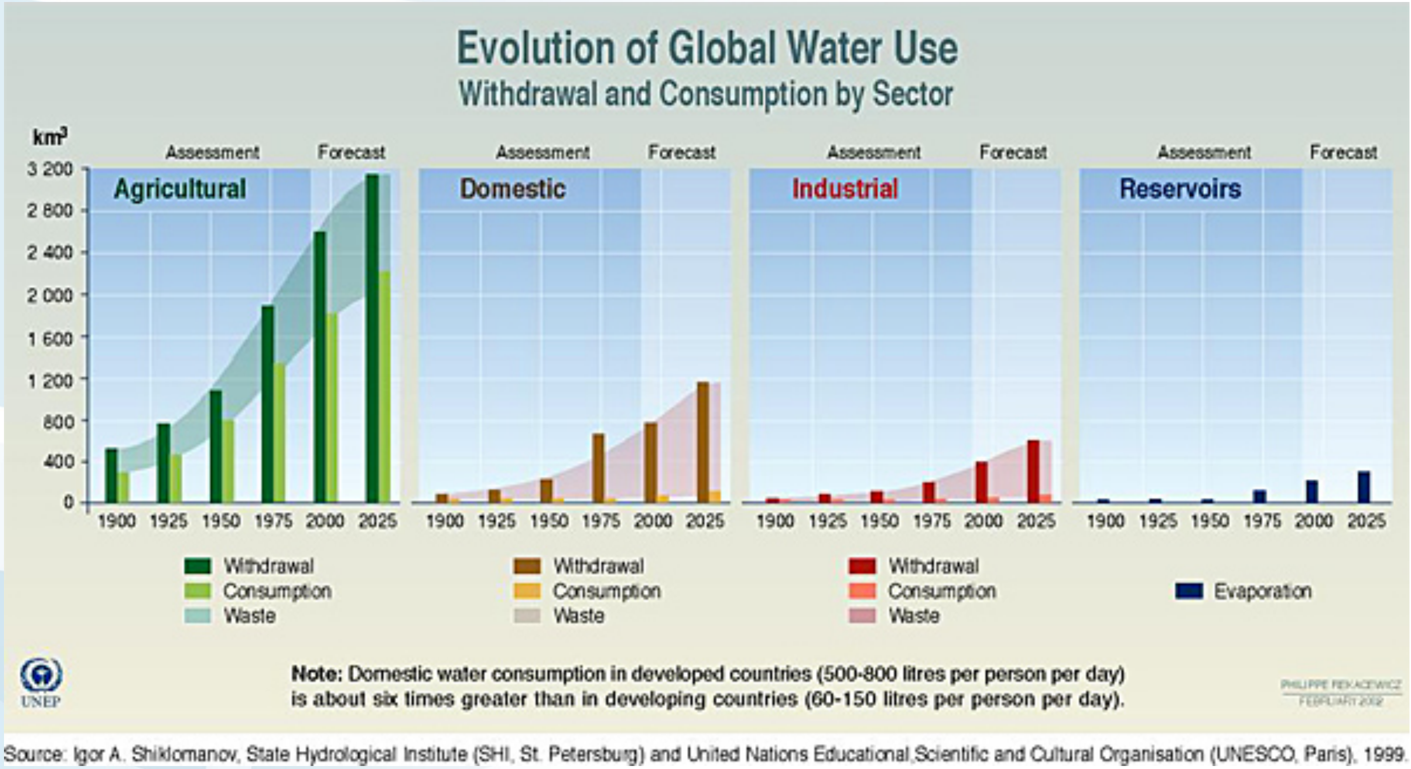
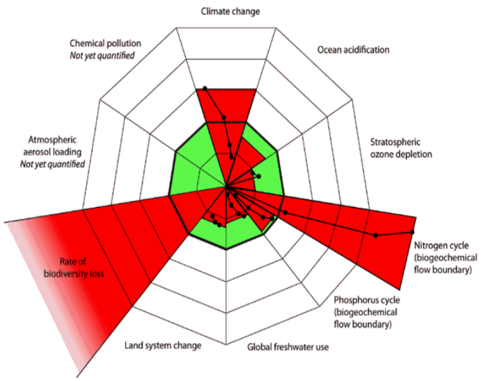
Future trends



Humanity approaches planetary boundaries



Geographical heterogeneity

Water needs are different in different locations

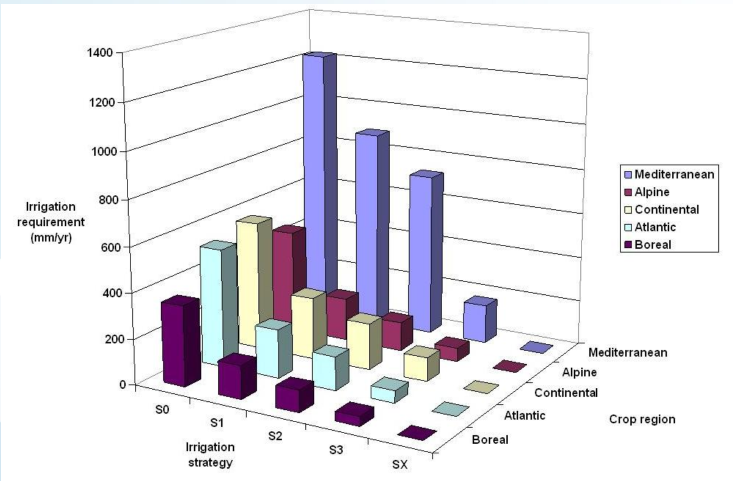


Figure 11: Average irrigation requirement for different irrigation strategies and crop regions.

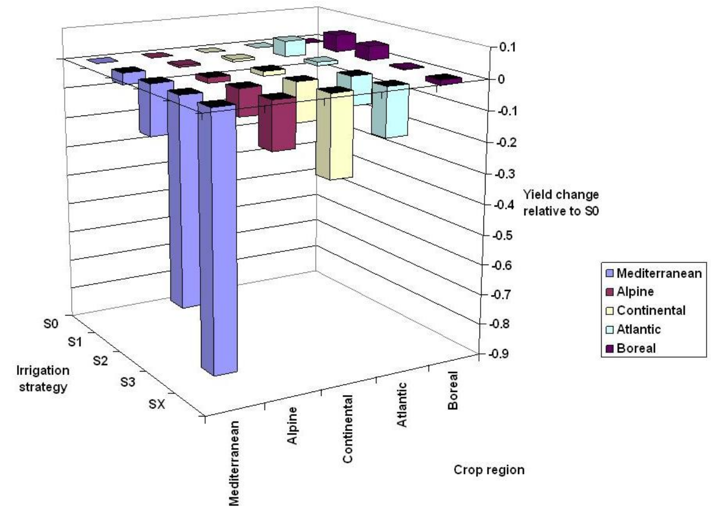


Figure 12: Average yield for different irrigation strategies and crop regions (given as relative yield to irrigation strategy S0).

Source: Water Requirements for Irrigation in the European Union, JRC Scientific and Technical Report, 2008

A rational decision maker would attempt to make use of competitive advantages of regions

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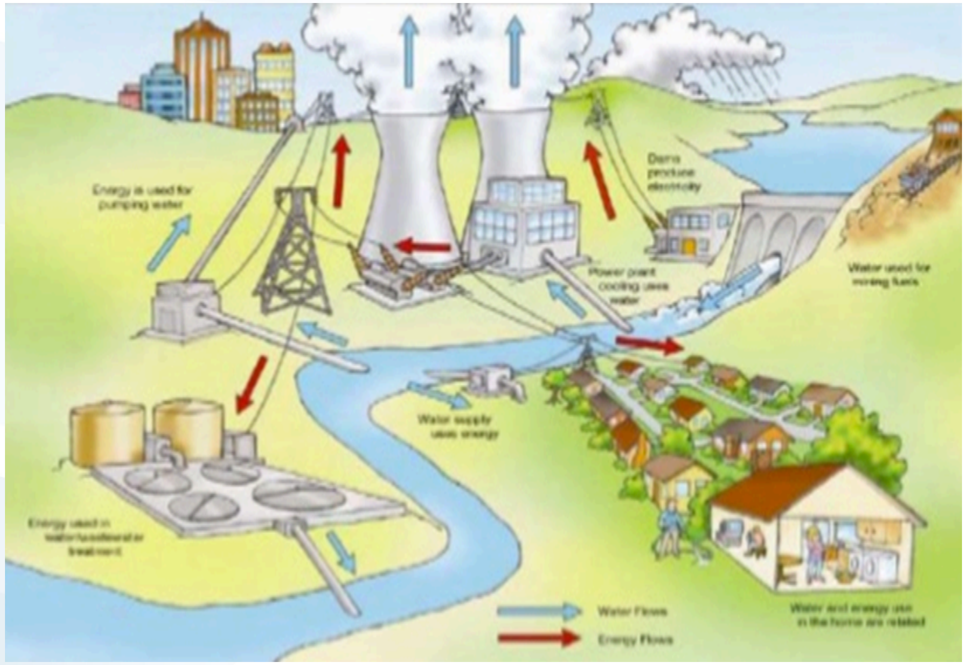
Food-water-energy nexus



- Currently decisions are often made in an un-coordinated way
- Synergies and tradeoffs between agri-food and energy sectors for water, land and other natural resources/ecosystem services to be found

Questions?

Part 1-2:

Using models to support policy decisions

Systems Analysis

… is the art of using models for assisting in making decisions

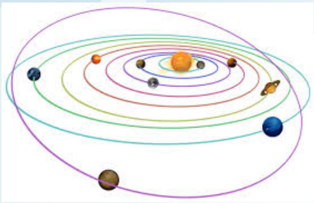
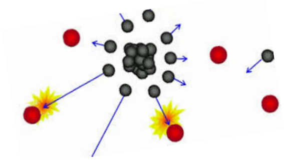
A model is a simplification of reality – useful for:

- Explain
- Guide data collection
- Illuminate core dynamics
- Suggest dynamical analogies
- Discover new questions
- Promote a scientific habit of mind
- Bound (bracket) outcomes to plausible ranges
- Illuminate core uncertainties
- Offer crisis options in near-real time
- Demonstrate tradeoffs/ suggest efficiencies
- Challenge the robustness of prevailing theory through perturbations
- Expose prevailing wisdom as incompatible with available data
- Train practitioners
- Discipline the policy dialogue
- Educate the general public
- Reveal the apparently simple (complex) to be complex (simple)

Source: Epstein (2008)

Models

- Descriptive
- Graphical
- Mathematical
- Statistical
- Gamification
- ….

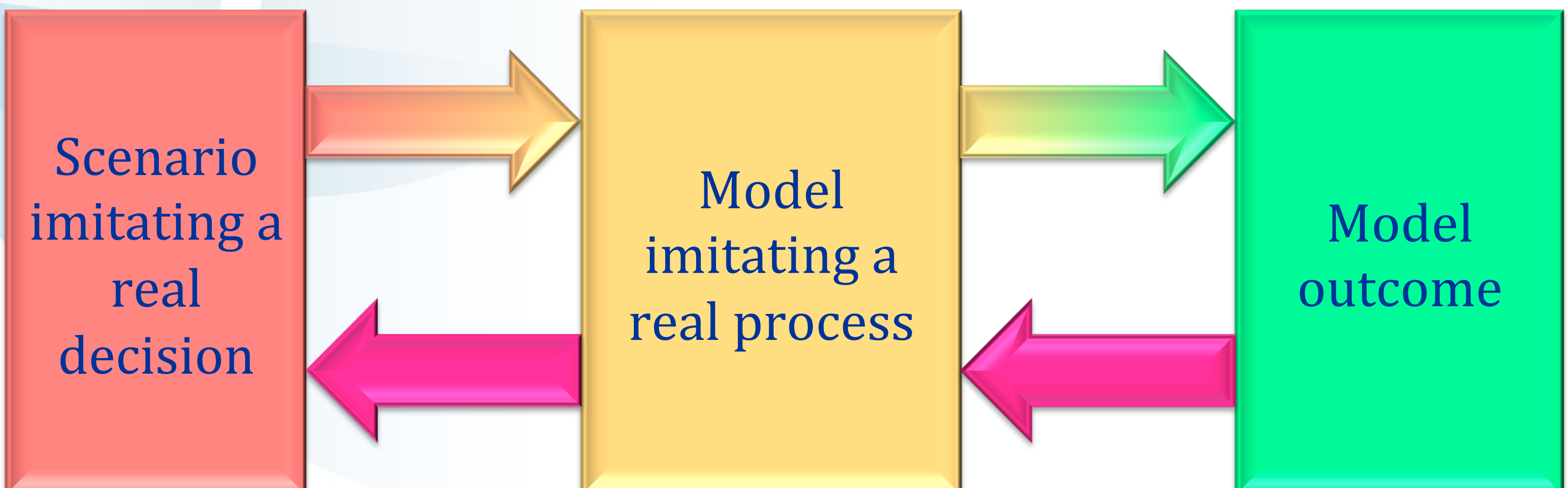
Straightforward causality Laws of classical physics	Organized complexity Systems analysis	Disorganized complexity Statistics
		

Source: Warren Weaver, Rockefeller Foundation Annual Report, 1958

How models can be used to support decisions?

Reality

Model = artificial reality



How models can be used to support decisions?

Test pre-defined options/ scenarios

Simulations

Options/scenarios to be developed, in e.g., a participatory exercise

Limited to the currently considered alternatives

Derive “optimal” solutions

Optimization

Possible to discover a new solution not considered before

Feasibility to be checked

Optimization models

x Vector of decisions

p Vector of parameters

$F(x,p)$ Objective function

$$F(x,p) \to \min$$
$$x \in X$$

$$\Rightarrow \quad x^*(p)$$

Equivalent to:
$$-F(x,p) \to \max$$
$$x \in X$$

Questions?

Part 1-3:
Linear optimization: Introduction

Linear optimization: A two-crop example

Crop A		Crop B
x_A	Production of a crop type	x_B
c_A	Marginal cost	c_B
w_A	Marginal water use	w_B

Crop B is cheaper to produce

Crop B requires more water to produce

$$c_A x_A + c_B x_B \rightarrow \min$$

$$w_A x_A + w_B x_B \le w$$

$$x_A + x_B \ge D$$

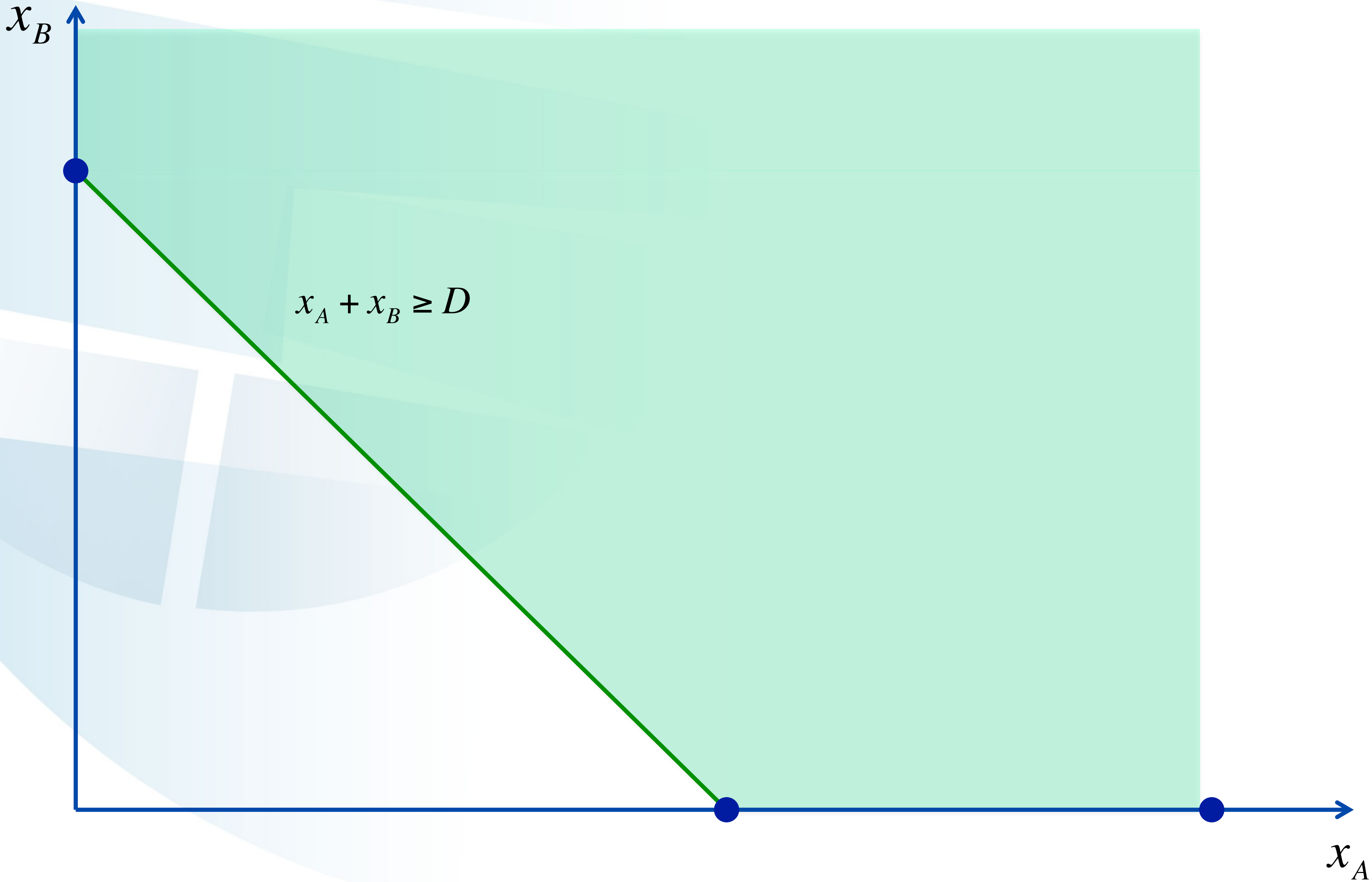
$$x_A \ge 0$$

$$x_B \ge 0$$

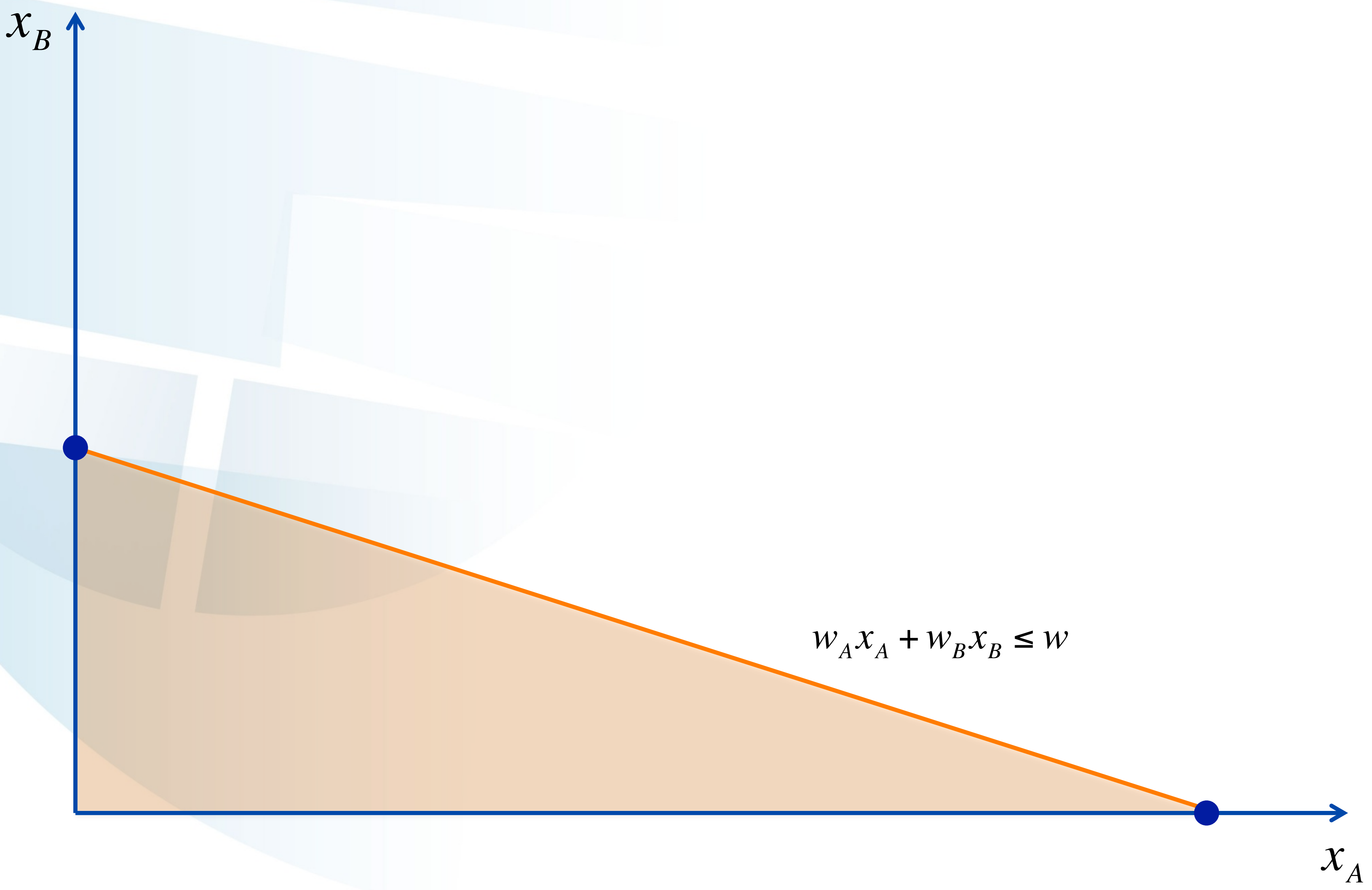
Total available water

Production target

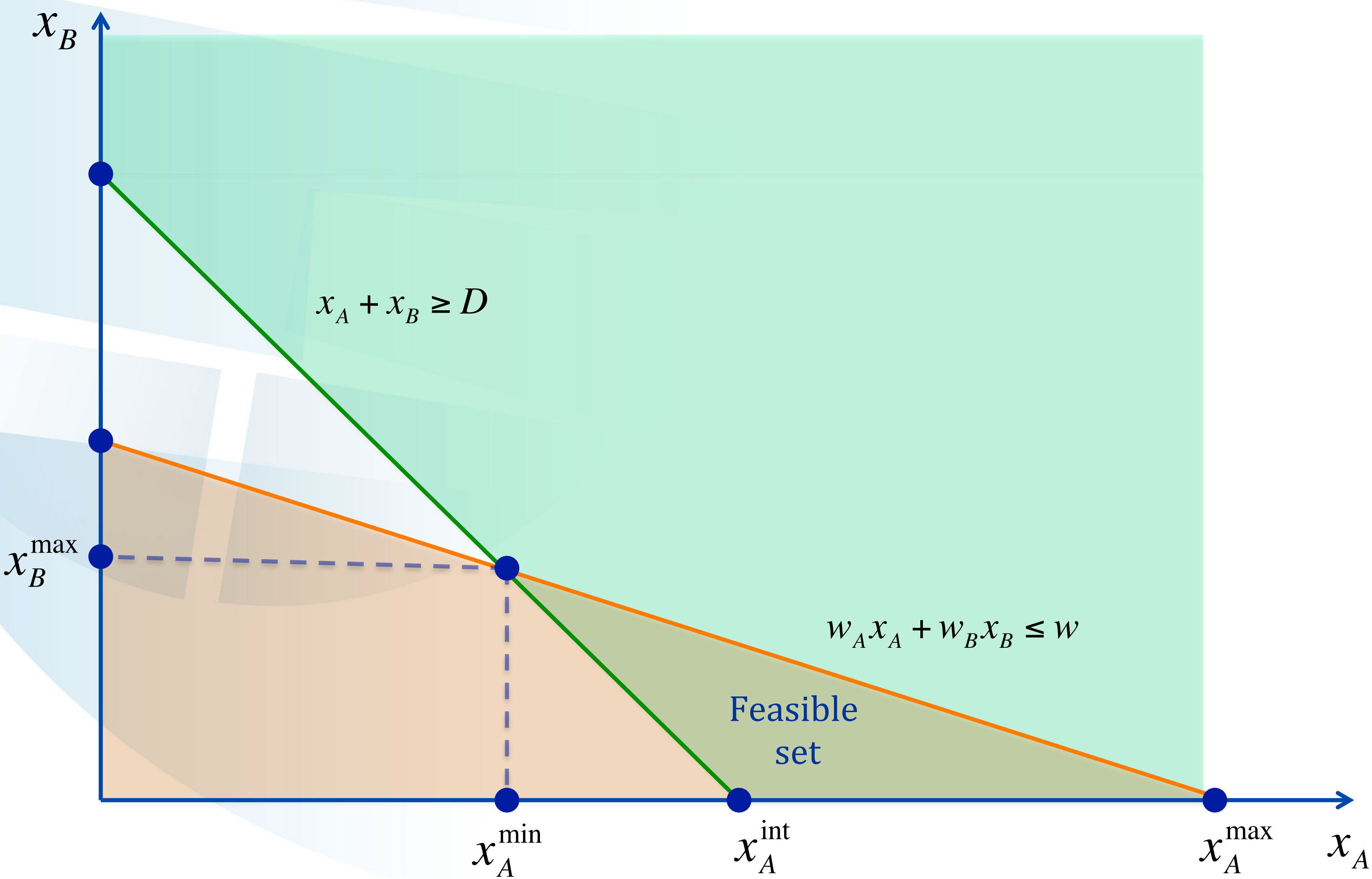
A two-crop example: A feasible set



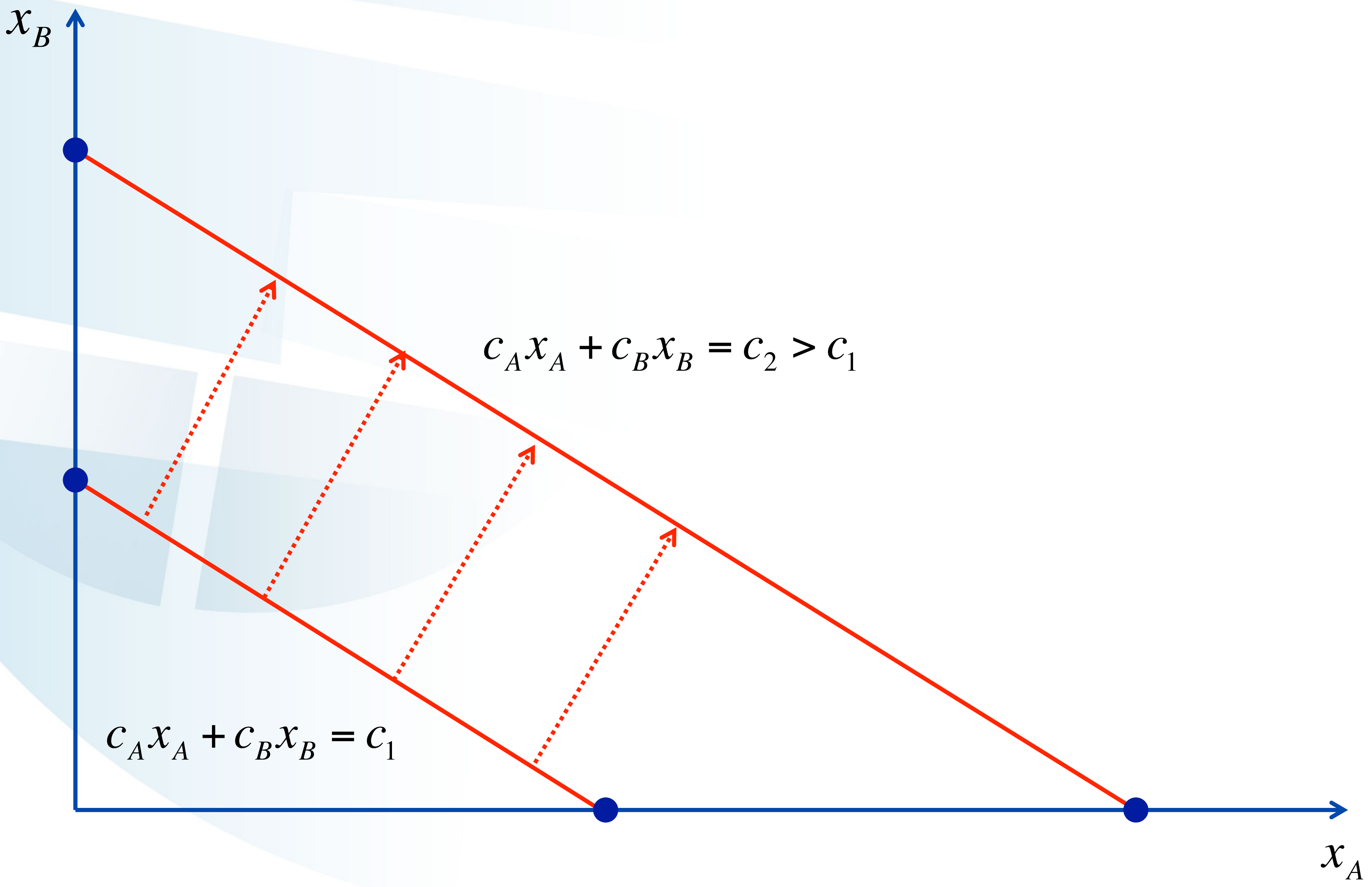
A two-crop example: A feasible set



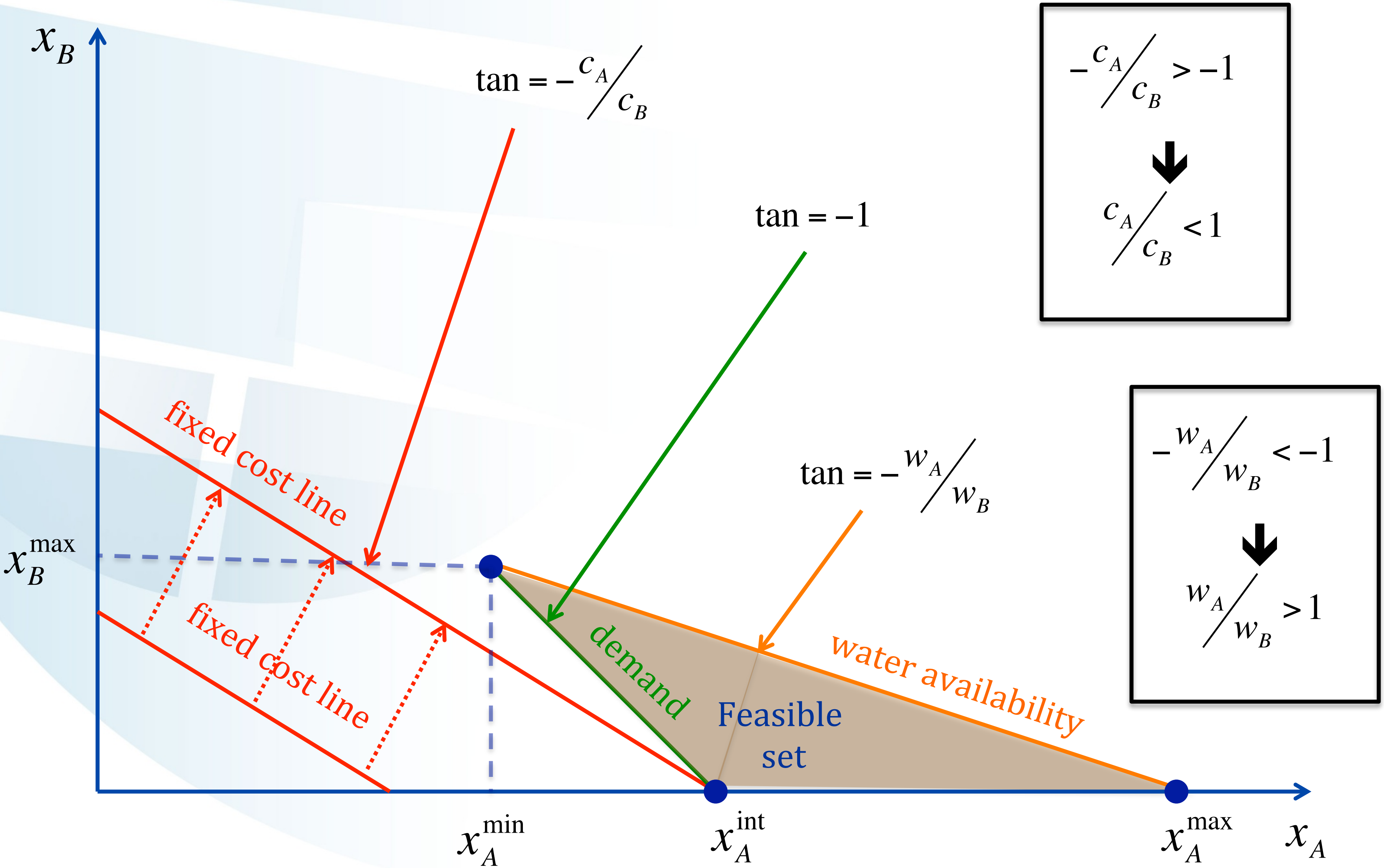
A two-crop example: A feasible set



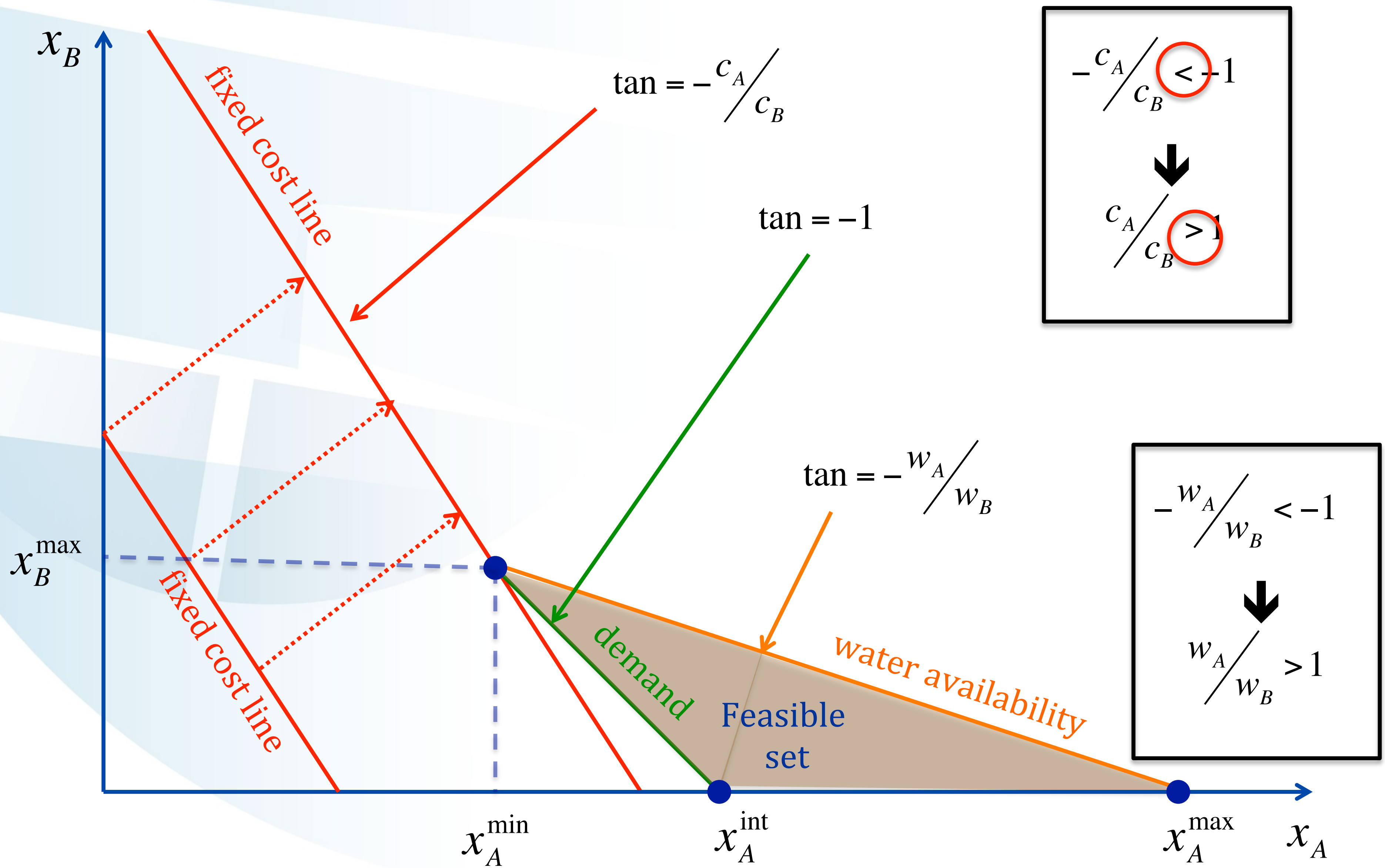
A two-crop example: Cost levels



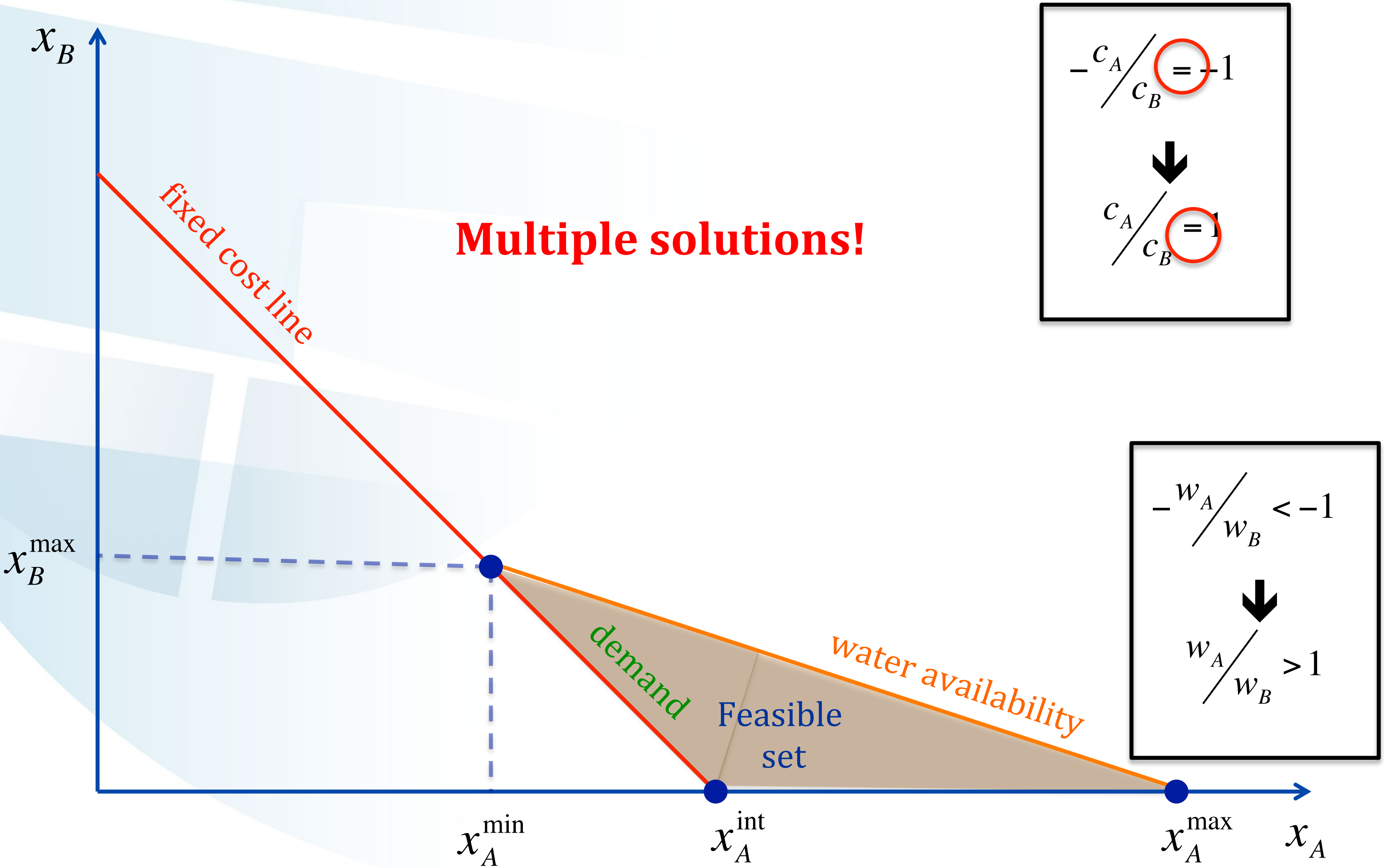
A two-crop example: Minimum-cost solution



A two-crop example: Minimum-cost solution



A two-crop example: Minimum-cost solution



A two-crop example: Minimum-cost solution

x_B

Exercise your understanding

?

Consider:

$$-{w_A}/{w_B} > -1$$

$$\Downarrow$$

$${w_A}/{w_B} < 1$$

x_A

More constraints within this framework

- Availability of land
- Availability of labor
- Soil type and productivity
- Fertilizers
- Water pollution
- Diversity of crops
- Rotation of crops
- Trade
- ....

Exercise your understanding

- Formulate these constraints mathematically

Questions?