Optimising Irrigation Planning with Non-Uniform Water Applications

Bennie Grové and Marcill Venter
Department of Agricultural Economics

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Acknowledgement

Water Research Commission (WRC) for initiating, managing and funding the research project on

“THE OPTIMISATION OF ELECTRICITY AND WATER USE FOR SUSTAINABLE MANAGEMENT OF IRRIGATION FARMING SYSTEMS”

"IRRIGATION IN A CHANGING ENVIRONMENT"

- Rising electricity costs
  - Increases the cost of applying irrigation water
    - What is the optimal level of water application?
    - Is it worth while to apply water to achieve maximum yield?
- Water resources under pressure
  - E.g. Environmental flows
    - Catchments are over-allocated
      - Water curtailments ?
      - Reduced security of supply ?
  - Population growth

PARADIGM SHIFT (ENGLISH ET AL.,2002)

- Old paradigm
  - Apply irrigation water to achieve biological objective of maximizing production
- Rising electricity costs and water scarcity/reduced water supply reliability
  - Emphasise the importance of:
    - Balancing the cost of applying irrigation water to a specific crop with the expected economic benefit from doing so.
    - Opportunity cost of water
      - Trade-off between alternatives
- New paradigm
  - Optimise water use to increase profitability

NEW GENERATION DECISION SUPPORT

- The fundamental procedures for irrigation scheduling/planning
  - relatively straight forward and simple
- Providing decision support to optimise water use to improve profitability
  - complex
- DSS under new paradigm should consider (Hillyer, 2011)
  - Economic consequences (opportunity cost of water)
  - Farm level constraints and the conjunctive scheduling of all irrigation fields
  - Deficit irrigation (yield reduction)
  - Full season forecasting in order to facilitate planning
- Best addressed by optimisation

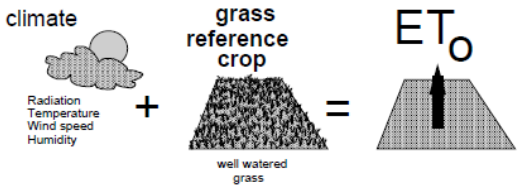
BASIC PREREQUISITES

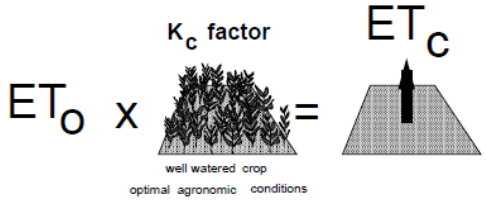
- Soil water is a stock resource (Dynamic)
  - Irrigation decisions in one period influence the availability of water in subsequent time periods and ultimately crop yield
- Applied water vs consumed water
  - Farmer control gross water applications
  - Water consumption determines crop yield
  - What is happening in the soil?
- Stochastic nature
  - Weather (crop water demand and rainfall)
  - Water deficits will increase crop yield variability
  - Risk preferences

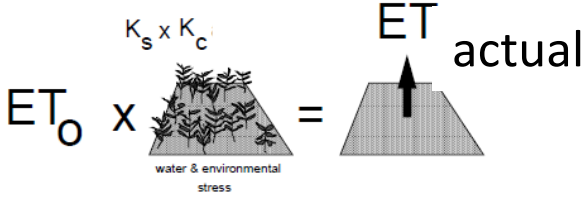
OBJECTIVE

- The main objective of this research was to develop an optimisation model that:
  - Considers soil water as a stock resource
    - daily dynamic
  - Explicitly model the relationship between applied water and crop yield
    - Non-uniformity of water applications

PROCEDURES

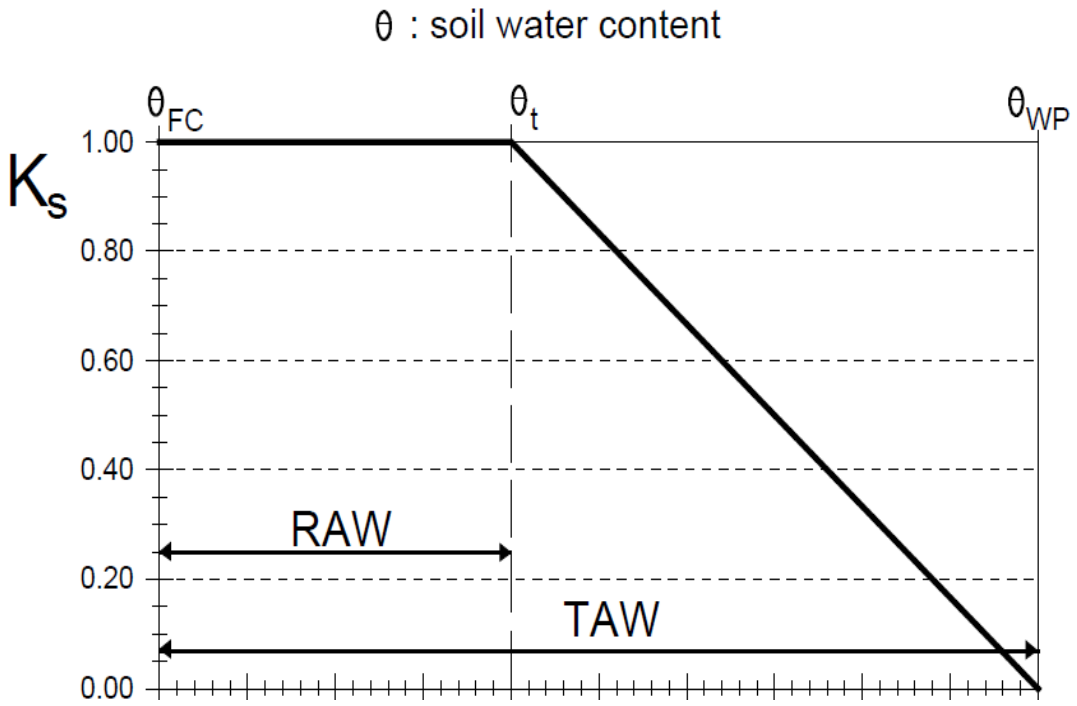






- Reference ET (ET_0)
  - Penman-Monteith
- Maximum crop ET_c
- Water stress conditions
  - ET_C is adjusted to determine ET_{actual}
  - Need water budget calculations to calculate K_s

K_S-ADJUSTMENT FACTOR



TAW: amount of water that a crop can extract from its root zone

RAW: fraction of TAW that a crop can extract from the root zone without suffering water stress

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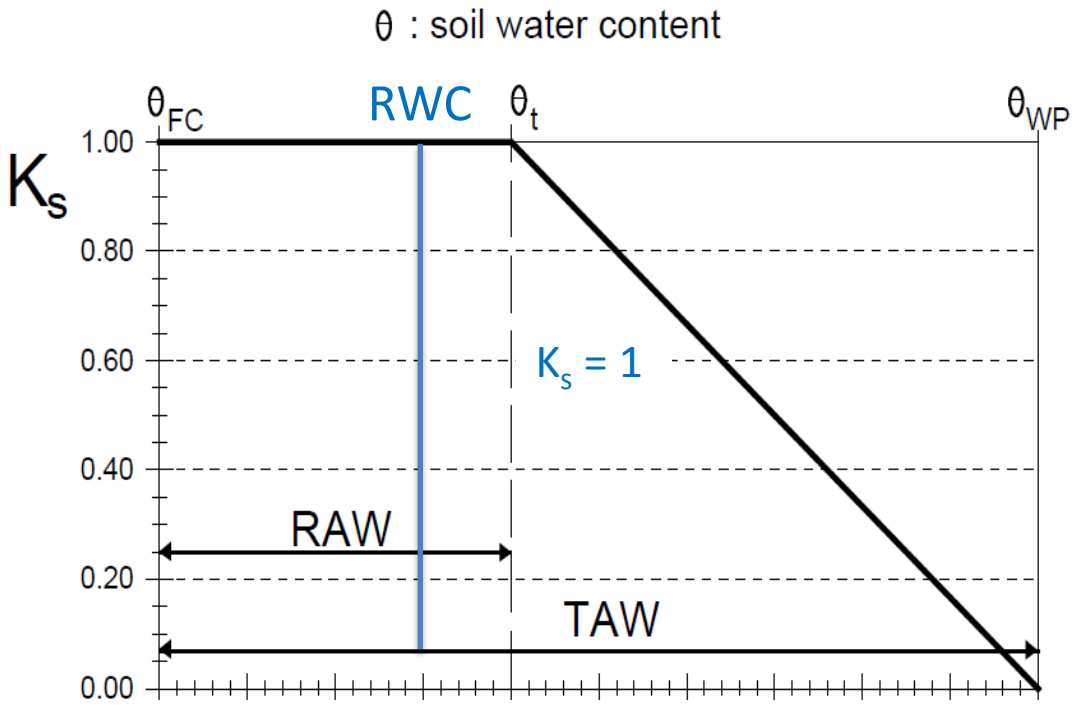

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RAW: fraction of TAW that a crop can extract from the root zone without suffering water stress

RWC: water content of the root zone

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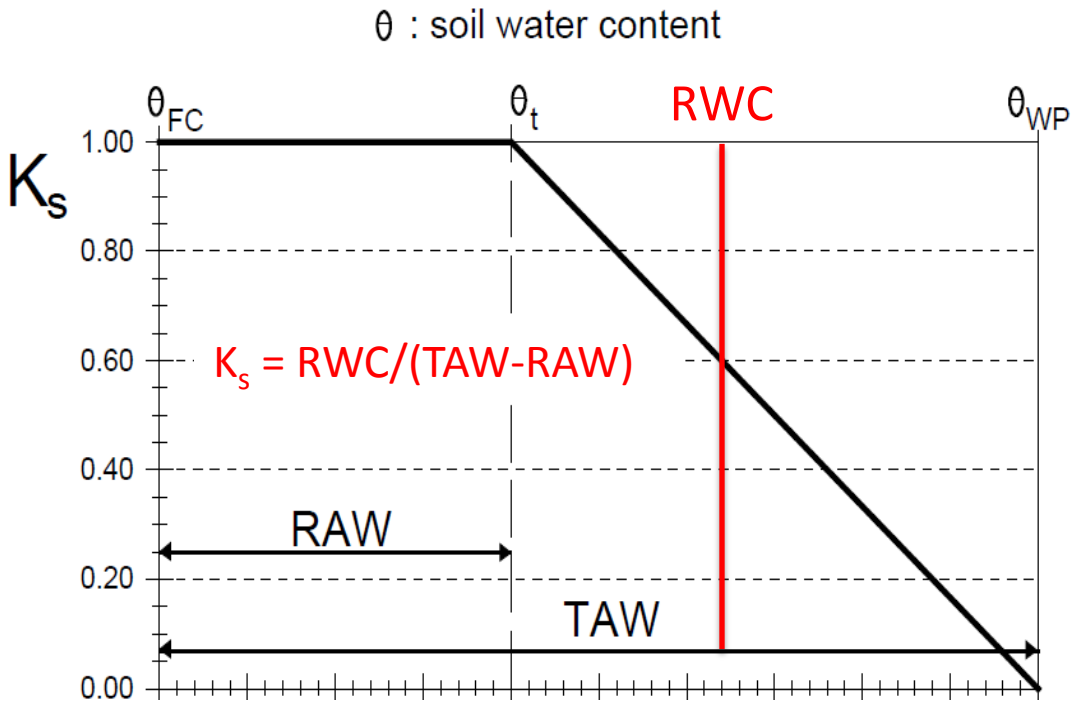

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RWC CALCULATIONS

- Different from FAO 56
  - 2 cascading water layers
    - Root zone
    - Potential root zone
  - Allows water to be stored below root zone
  - Daily instantaneous calculations

$$RWC_t = \min \begin{vmatrix} RWC_{t-1} - ETa_{t-1} - R_{t-1} + IR_{t-1} + TR_t - BPR_{t-1} \\ RWCAP_t \end{vmatrix}$$

$$PRWC_t = \min \begin{vmatrix} PRWC_{t-1} + BPR_t - TR_t - PERC_t \\ PRWCAP_t \end{vmatrix}$$

CROP YIELD ESTIMATION

- Water budget calculations
  - K_s
  - ET_{actual}
  - Relative evapotranspiration deficits
- Relative evapotranspiration crop yield estimates
  - Stewart multiplicative
    - Non-linear
- What about the relationship between applied water and crop yield?

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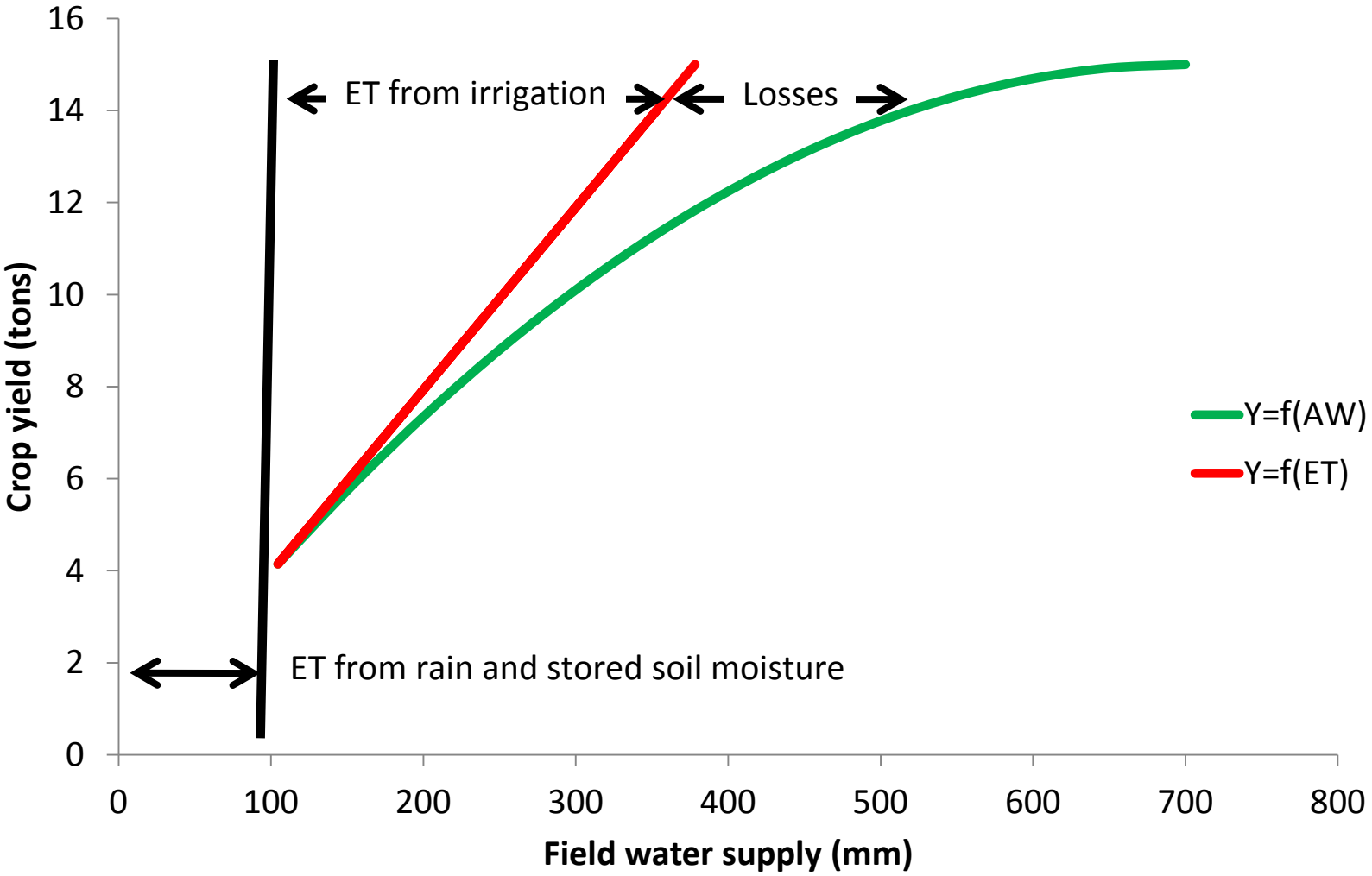
APPLIED WATER AND CROP YIELD



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Uniform water applications

WP

FC

Uniform water applications

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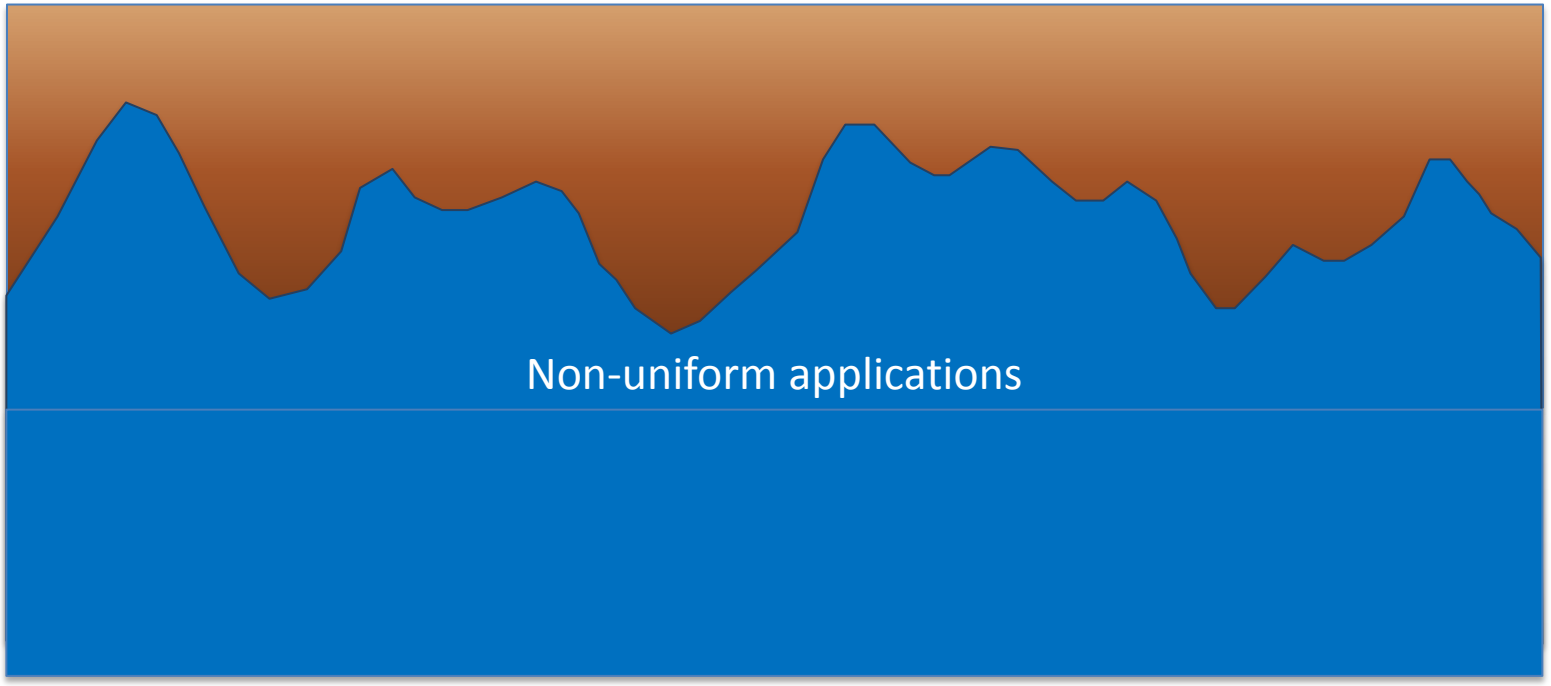
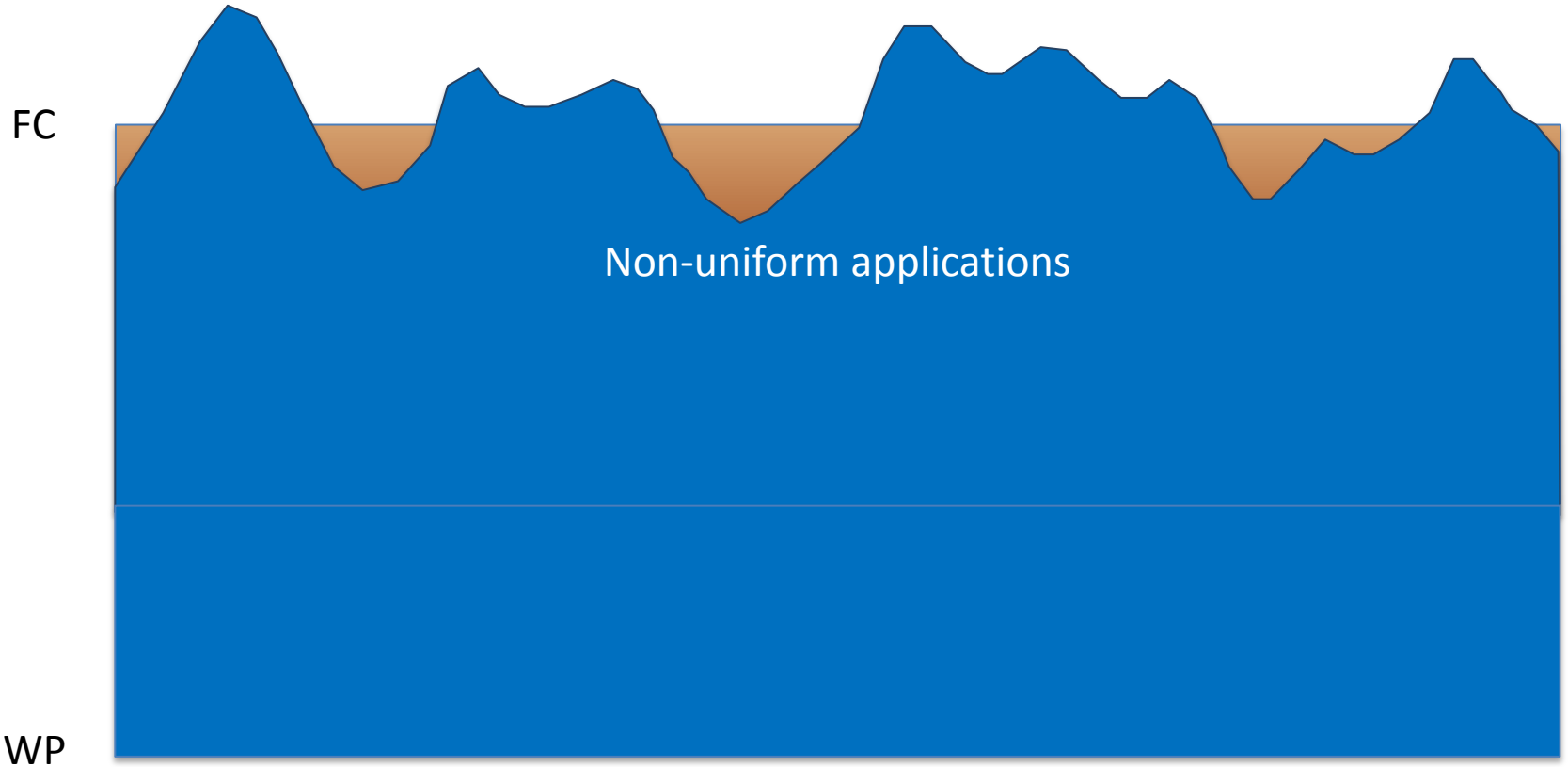


WP


FC
Non-uniform applications
WP

INCORPORATING NON-UNIFORMITY INTO MODELS

- Assume statistical relationship
  - Continuous relationship
  - Apply to seasonal water applications
    - Ignore status of the water budget
- Multiple water budgets (Lecler)
  - Discrete relationship
  - Based on statistical distribution
  - Uniformly distributed between min and max

HOW MANY WATER BUDGETS?

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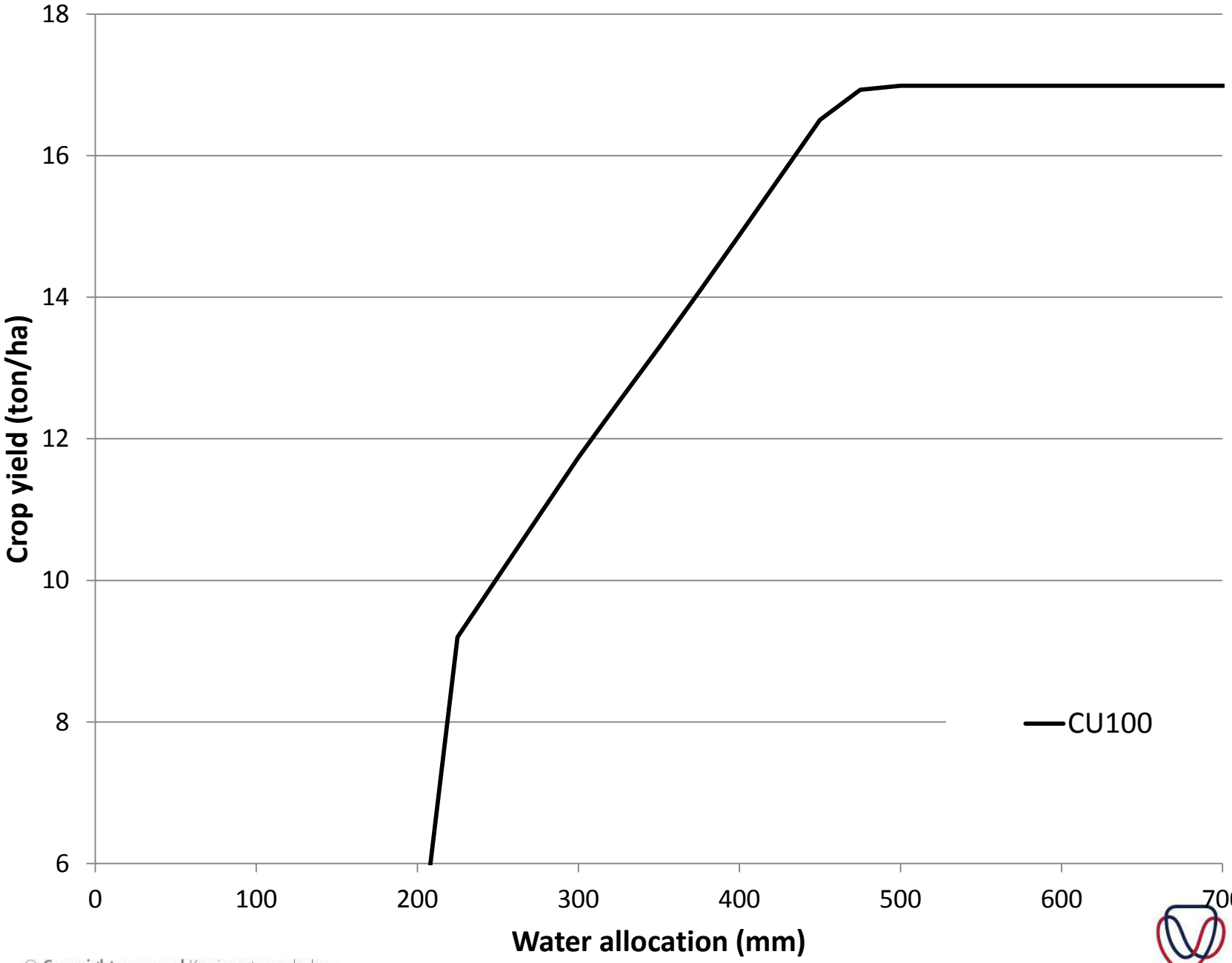

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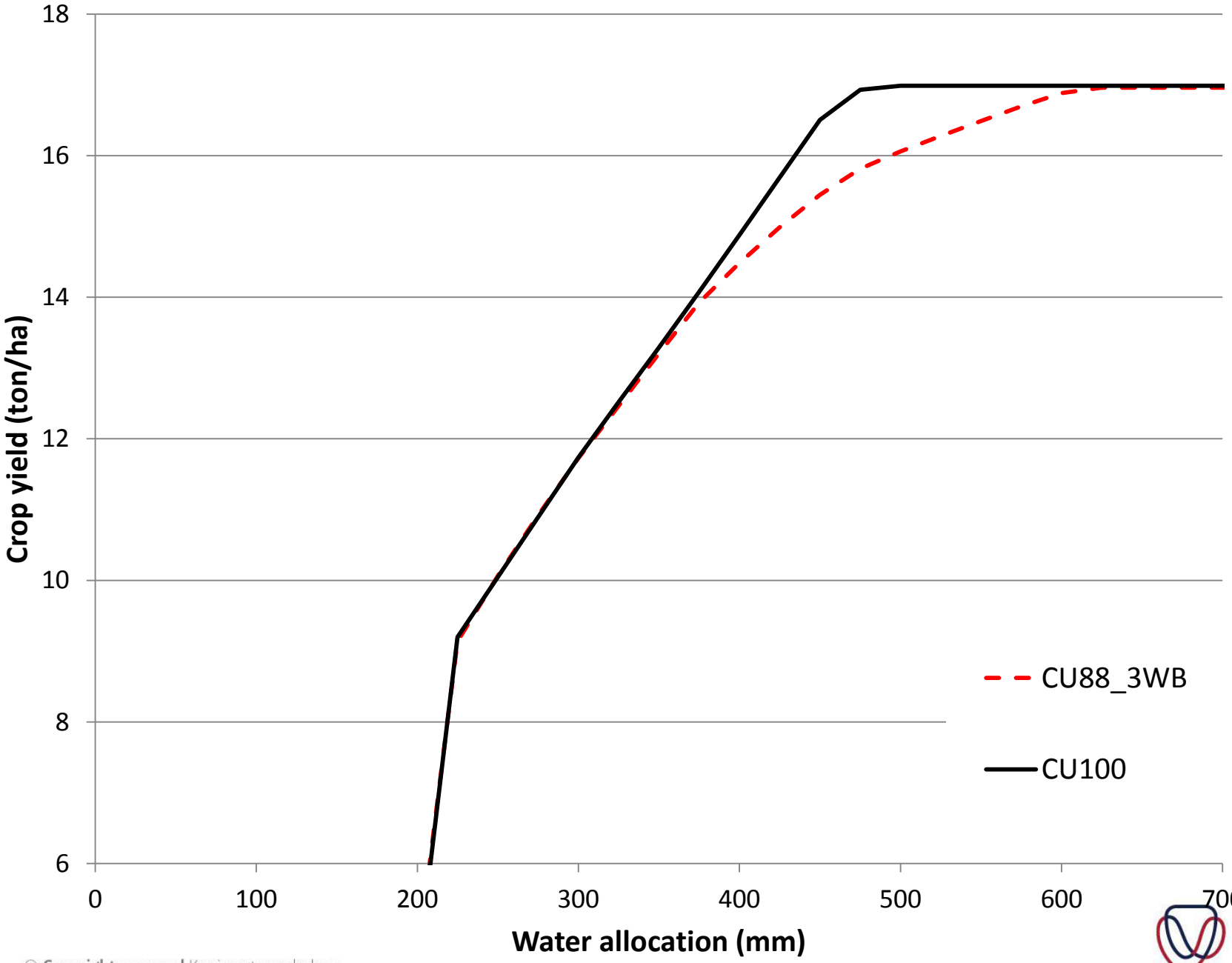

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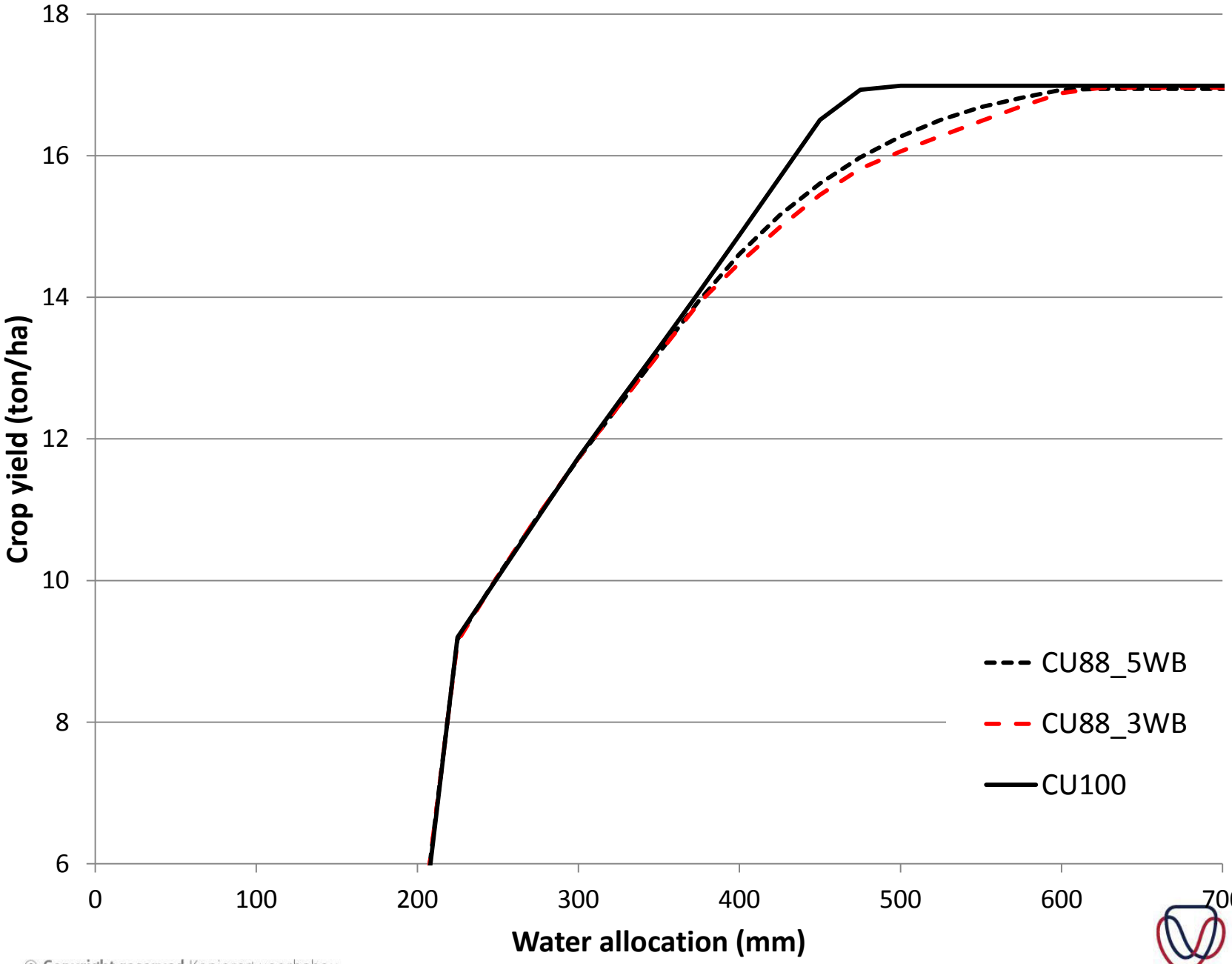

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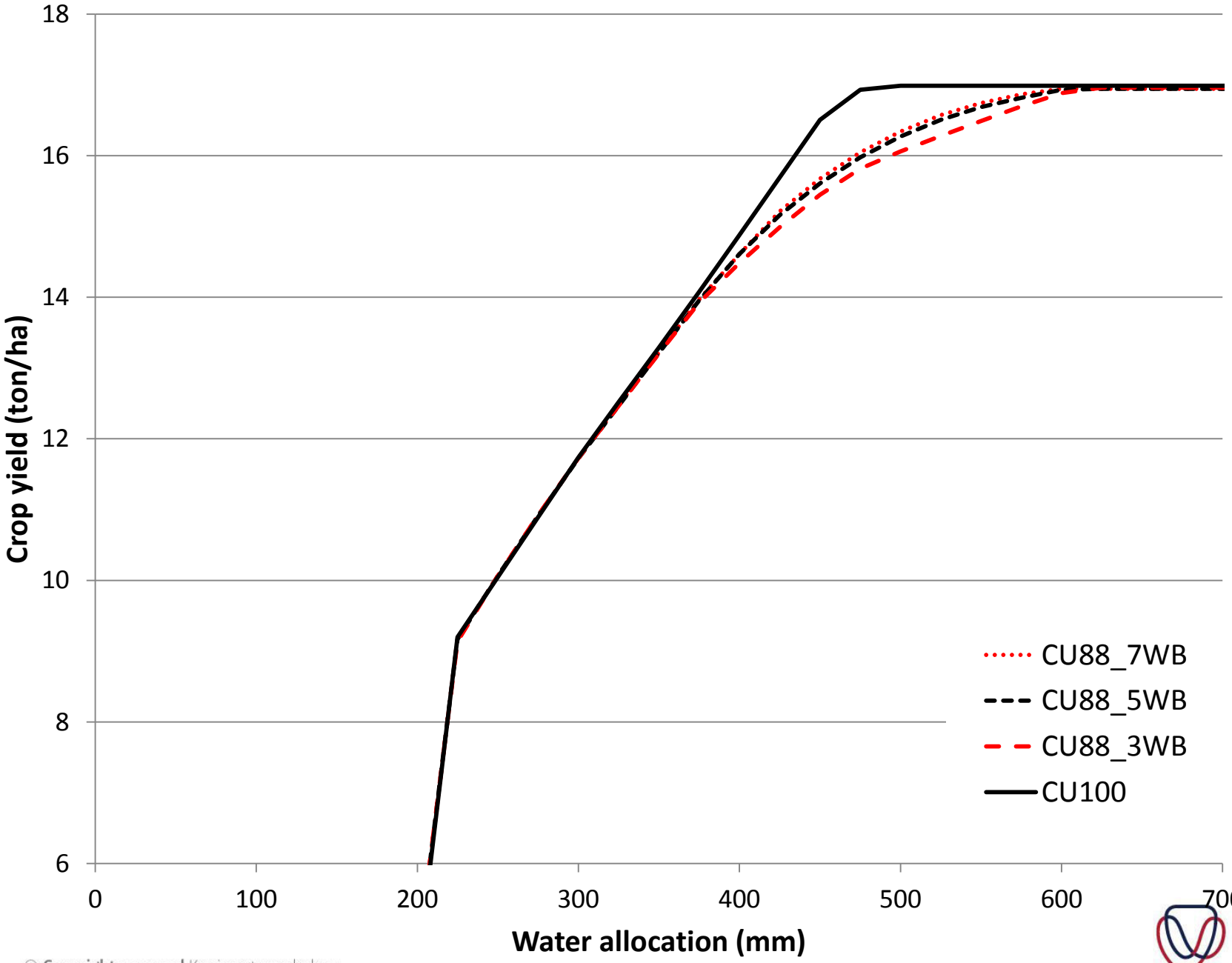

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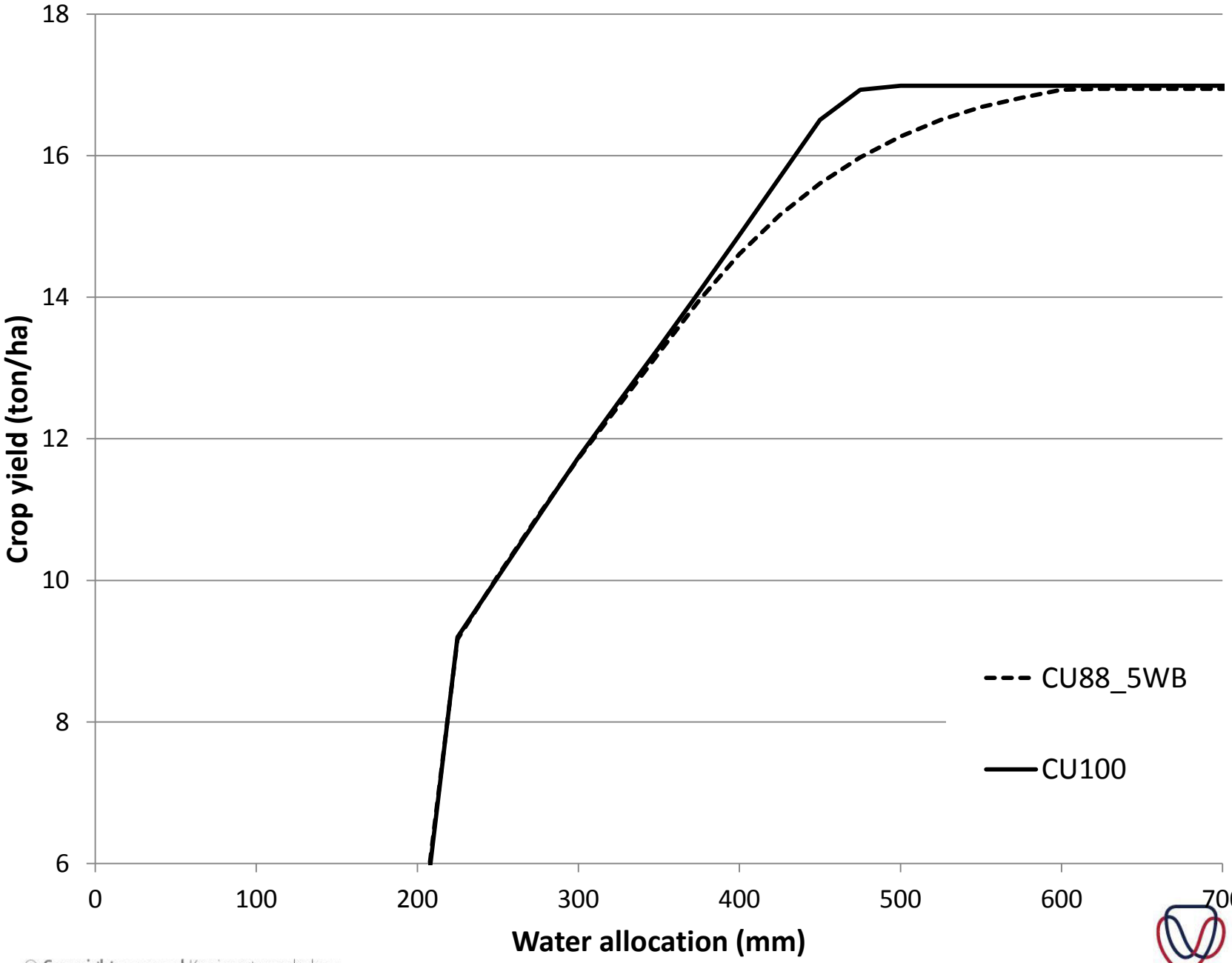

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WHAT IS THE IMPACT OF NON-UNIFORM WATER APPLICATIONS?

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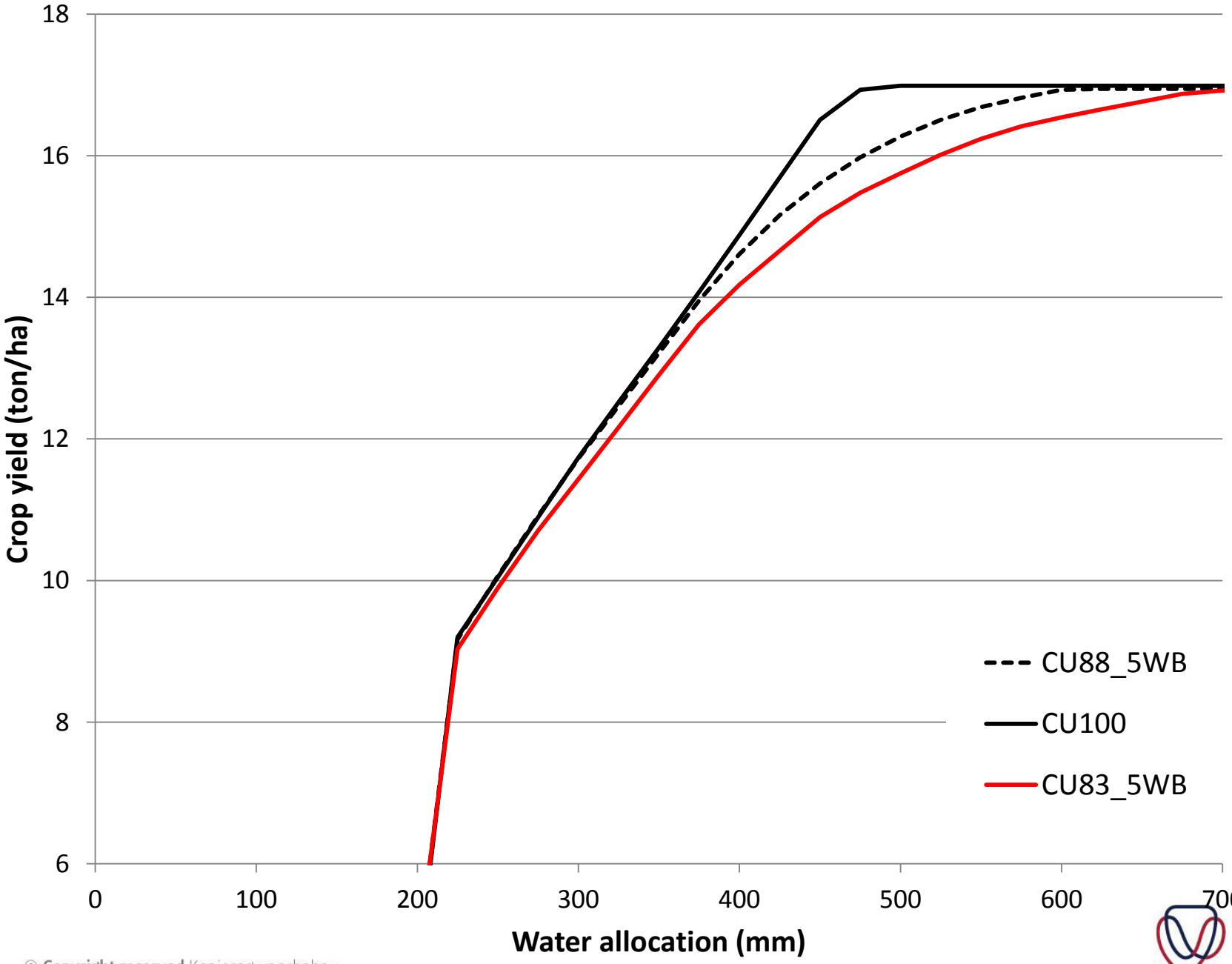

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WHAT ABOUT OPPORTUNITY COST OF WATER?

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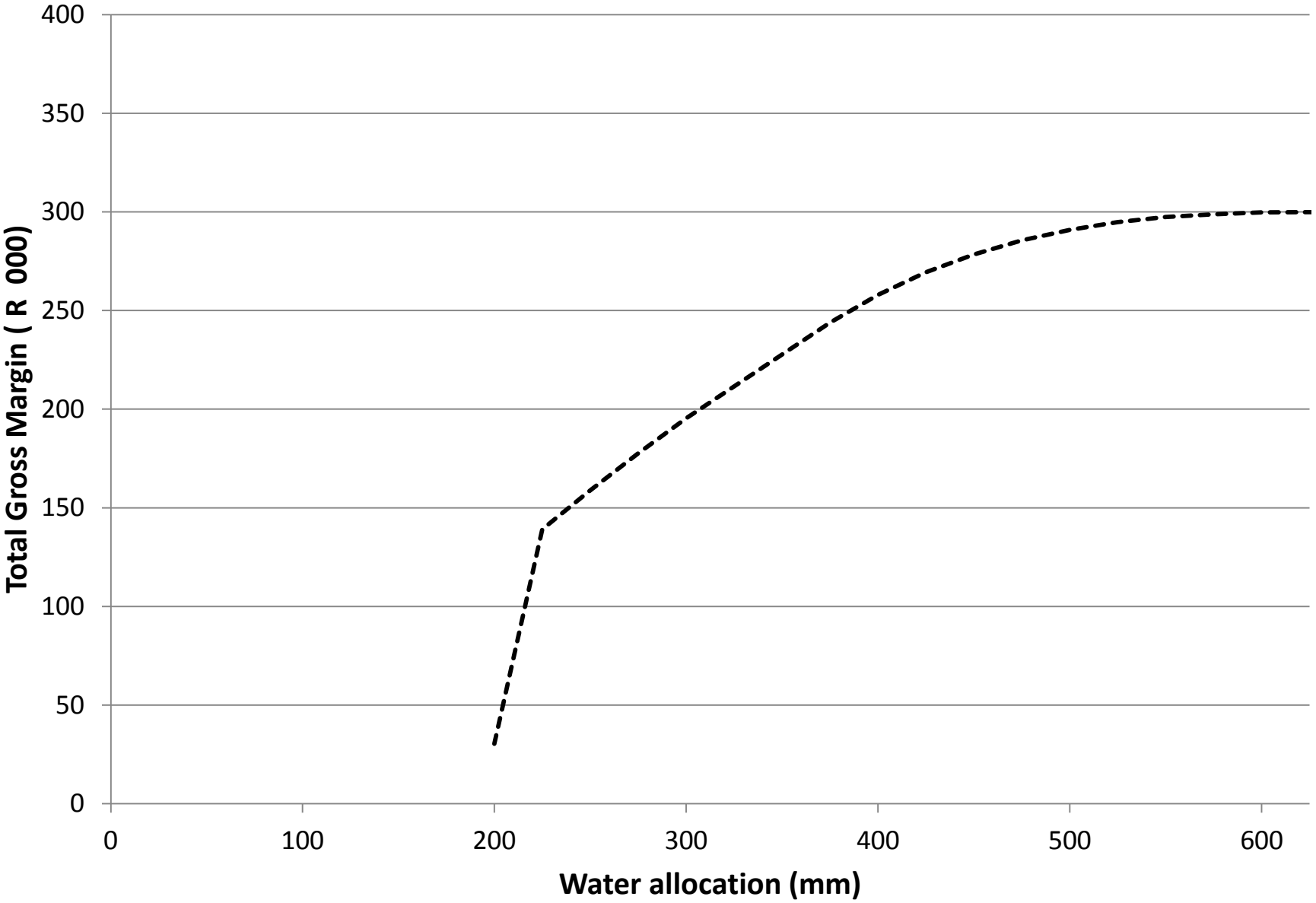

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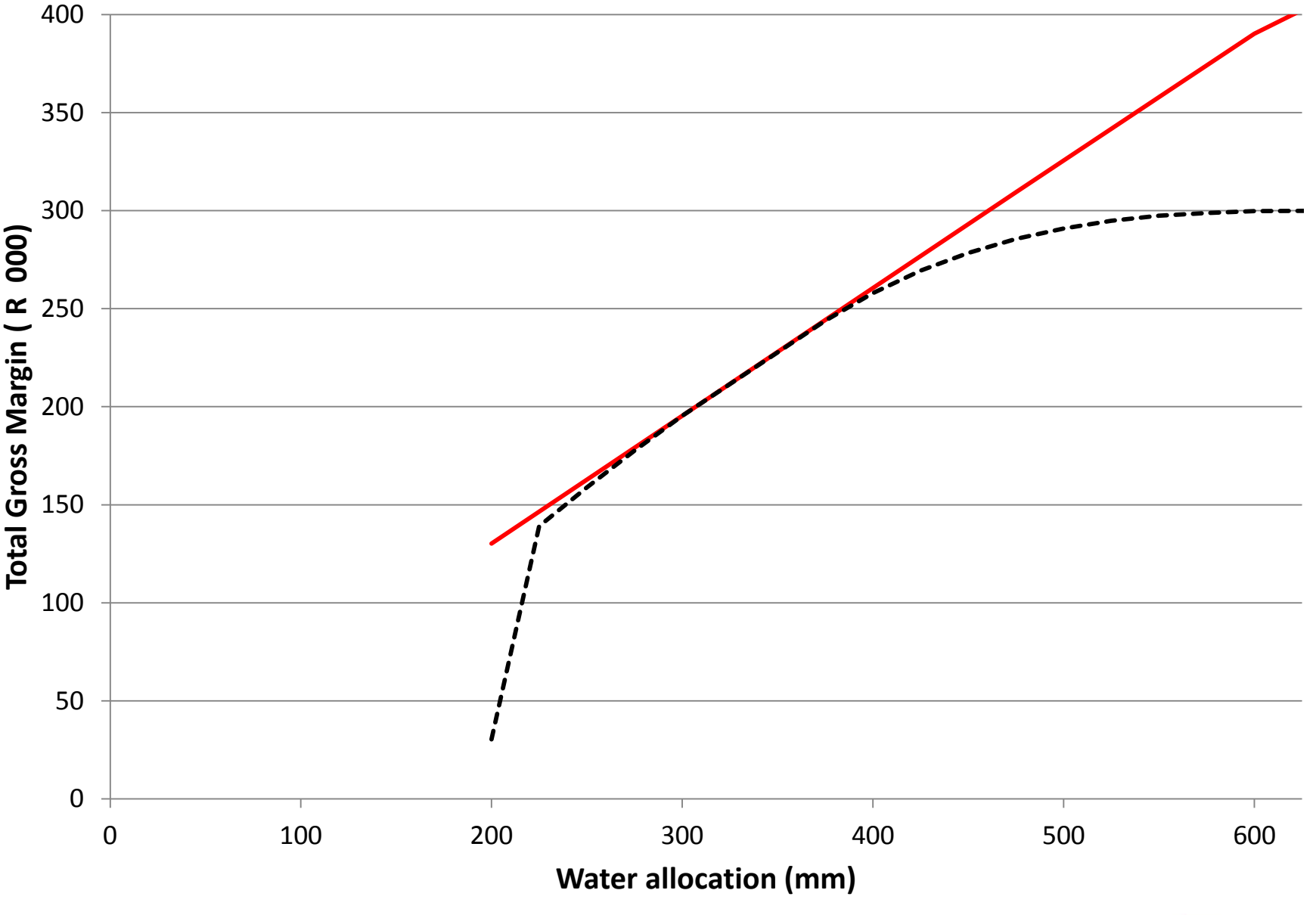

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ACHIEVEMENTS

- Optimise water use based on daily water budget
  - Stock nature of water
- Irrigation system specific water yield relationship
  - Non-uniform water applications
- Uses readily available information
- Results adhere to economic theory

THANK YOU

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BENNIE GROVÉ AND MARCILL VENTER
DEPARTMENT OF AGRICULTURAL ECONOMICS

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