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SCHOOL OF AGRICULTURAL & RESOURCE ECONOMICS

Managing multiple-use resources: optimizing reservoir water use for irrigation and fisheries

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55th AARES conference

9-11 February 2011

Crown Conference Centre, Melbourne, Victoria , Australia

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1.1 Background

- ❖Increasing in the number of reservoirs throughout the country (hydroelectricity, irrigation)
- ❖The demand from the uses, reservoir purposes and other factors affecting operations of the reservoir changing over time
  - ❖ Increase or decrease in irrigation demand
  - ❖ Single use ➔ multiple uses
  - ❖ Change in rainfall patterns

➔Policy makers face difficult choices in managing reservoir

1.2 Problem

- Reservoirs ➔ irrigate rice
- Fisheries ➔ secondary purpose and ➔ to help poor people who lost land and were displaced

➔Conflicts of interest in using water

- ❖ Rice ➔ water is stored as long as possible
- ❖ Fish ➔ water must be at low levels for harvest

➔ Prevent the management of the reservoir from achieving maximum benefits

➔ There is a need to refine and improve reservoir operation rules

1.3 Objective

- Define the optimal release strategy for a reservoir
  - ❖ Different purposes of reservoir water use (single use or multiple uses)
  - ❖ uncertain weather conditions
- The model ➔used for:
  - ❖ Existing reservoir (refine and improve the release strategy)
  - ❖ New reservoir project (propose the optimal release strategy and optimal irrigation area)
  - ❖ Develop optimal management strategy for other multiple-use resources: forest, river basins, and land

II. Model description

This is the problem of determining reservoir release strategy for rice, fish, and rice and fish production, considering:

❖Water release during a year

❖Uncertainty of rainfall

➔ Stochastic dynamic programming

❖ 8 stages (each 25 days long)

❖ State variable (s_n)

➔ Water level in a reservoir at the beginning of each stage (%RC)

❖ Decision variable (u_n)

➔ Water release at each stage (% RC)

❖ Stochastic variable

➔ Rainfall and reservoir inflows

❖ Transition equation

➔ Describing how states of the system change over time

$$s_{n+1} = s_n - u_n - e_n + q_n + i_n$$

❖ Objective function

$$V_n (s_n,u_n,q_n) = V_{rn}(s_n,u_n,q_n) + V_{fn}(s_n,u_n,q_n)$$

- ❖ $V_n (s_n,u_n,q_n)$: total profits (mVND)
- ❖ $V_{rn}(s_n,u_n,q_n)$: rice profits (mVND)
- ❖ $V_{fn}(s_n,u_n,q_n)$: fish profits(mVND)
- ❖ q_n : rainfall

Rice profit

$$V_{rn} = P_r Y_r - C_r \quad (1)$$

$$Y_r = Y_p\left(1-\sum_{n=1}^{N} ky_n\left(1-\frac{W}{W_0}\right)_n\right)$$

(Paudyal & Manguerra 1990)

P_r *is rice price*

C_r *is total rice production cost*

Y_r is rice yield (ton/ha)

Yp is the potential yield of rice (ton/ha)

ky_n is yield response factor in stage n

N is numbers of rice growing periods

W_0 is rice water requirements (%RC)

$W_n = u_n + q_n$ is water supplied including water release and rainfall

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Fish profit

$$V_{fn} = Y_f\left(1 + PCE_n\right) - C_f \qquad (2)$$

Y_f is fish yield

$$Y_f = \sum_{n=4}^{N-1}\sum_{j=1}^{\beta}(Y_{f_{nj}} P_{f_{nj}})$$

(Truong & Schilizzi 2010)

PCE_n is the physical concentration effects

(Tran et.al 2010)

Economic optimization

- The recursive equation

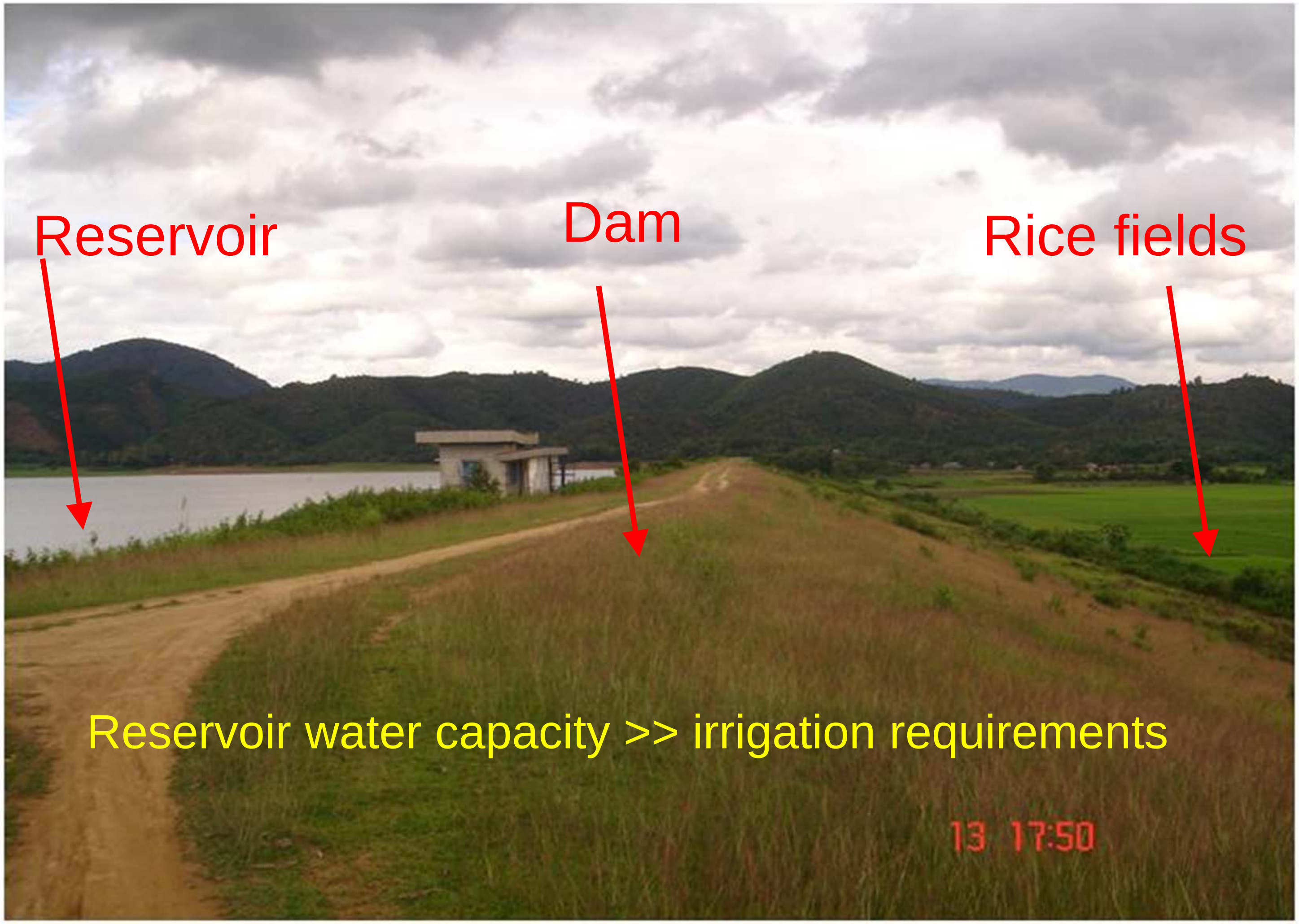
$$V_n\{s_n\} = \underset{u_n}{Max}\left[\sum_{k=1}^{m} p_n\{q_n^k\}\left(V_n\left(s_n, u_n, q_n^k\right) + \alpha V_{n+1}\left(s_n, u_n, q_n^k\right)\right)\right]$$

(n=N,….,1)

$$\sum_{k=1}^{m} p_n\{q_n^k\} = 1$$

➔define u*(u_1, u_2,…u_n)➔max expected net present value (ENPV) of the profits

III. Case study- Daton reservoir



Rice production and irrigation systems

Irrigate 2 rice crops during the dry season (December to June)

First crop: December – March

Second crop: April – July

Fish production

Stocking fingerlings: June
(beginning of the wet season)

Harvesting of fish: February – May
(in the dry season, low water levels)

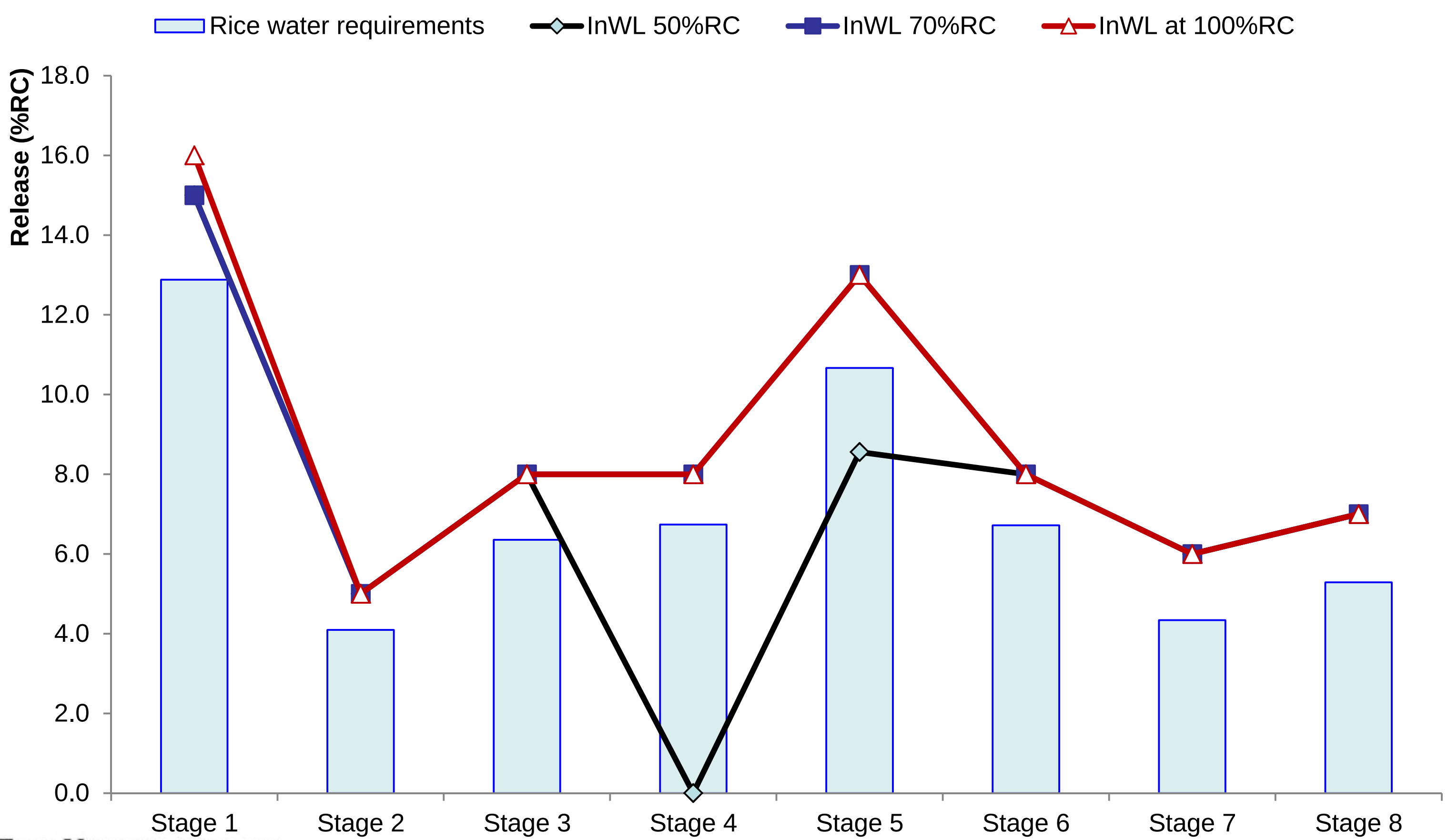
Results and discussion

- The optimal release strategy is defined for 3 production scenarios:
  - Scenario 1: Rice production
  - Scenario 2: Fish production
  - Scenario 3: Rice and Fish production
- These strategies are calculated for a range of the initial water levels from 100%RC to 10%RC
- Discussions focus on three representative initial water levels: 100%RC, 70%RC and 50%RC

The optimal release for Rice production

❖Adequate water ➔ released➔ satisfy the rice water requirement

❖residual water ➔ store ➔ for additional irrigation



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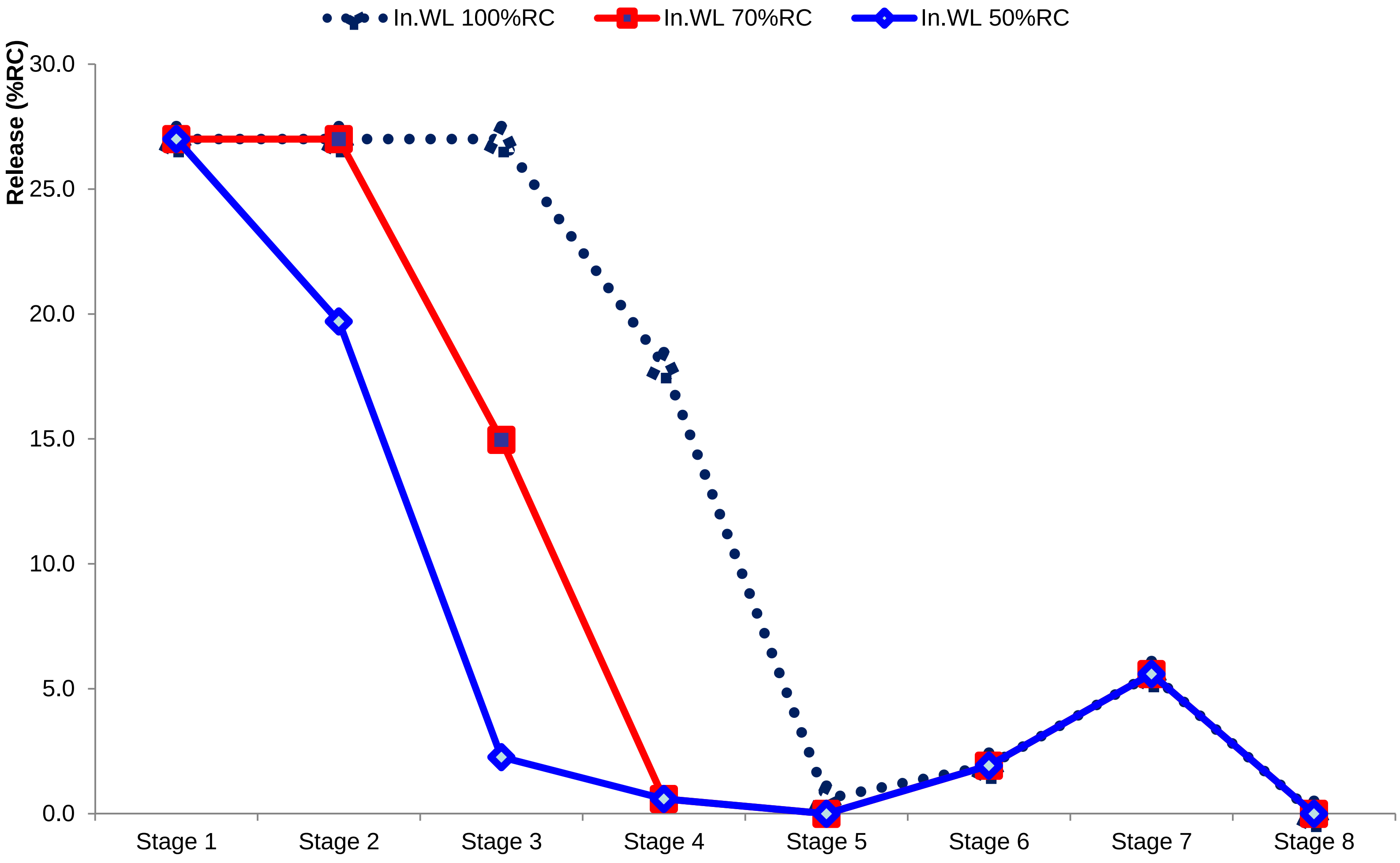
The optimal release for Fish production

Maximum releases can be made from stage 1-4

➔reservoir to low water levels prior to fish harvest



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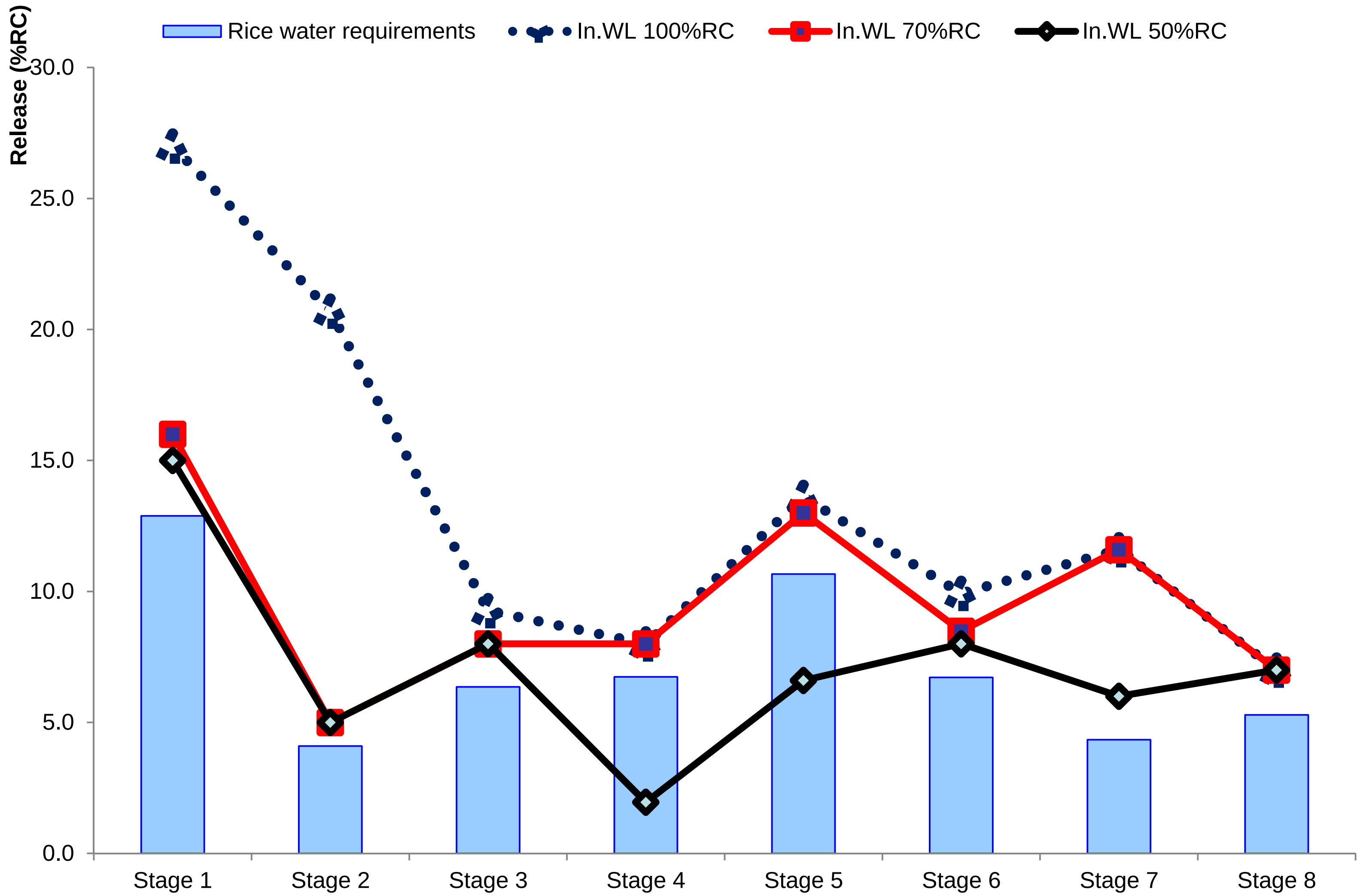
The optimal release for Rice and Fish



1. High initial water levels

Maximum releases can be made from stage 1-4

but residual water must

Satisfy the demand for rice in the remaining stages

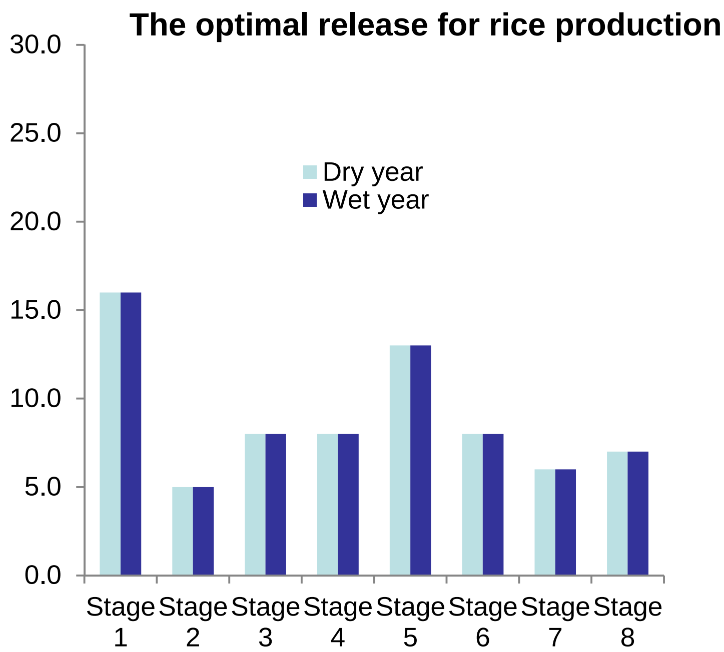
2. Low initial water levels

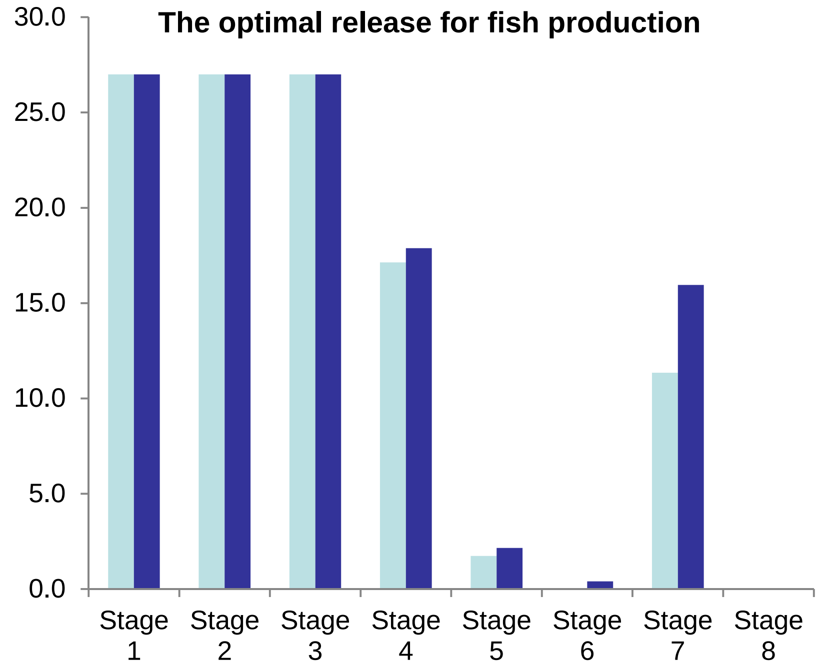
Release give priority to rice production

Regardless of

the demand of release for fish harvest

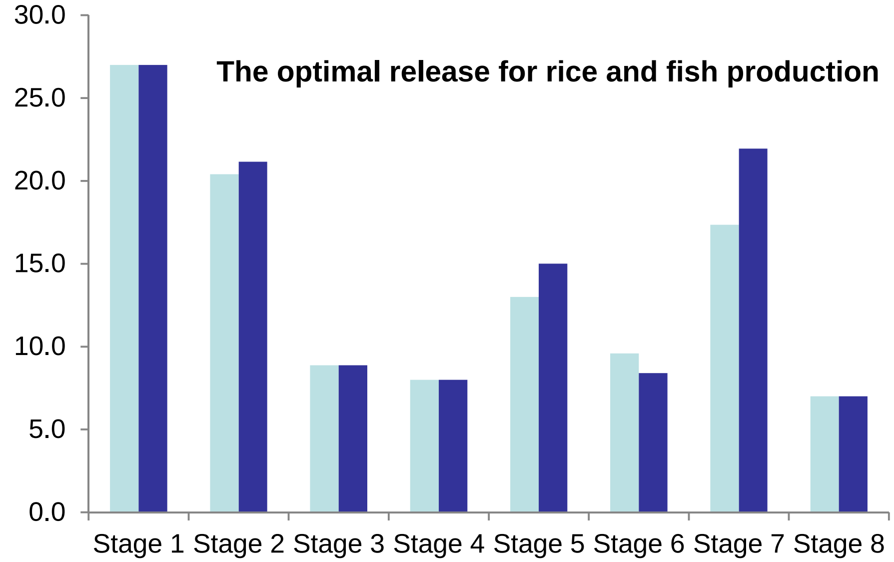
The effects of weather conditions (InWL 100%RC)





Rice: Weather conditions does not affect the release

Fish, and Rice and Fish:
In the wet year water is released higher than or equal in the dry year



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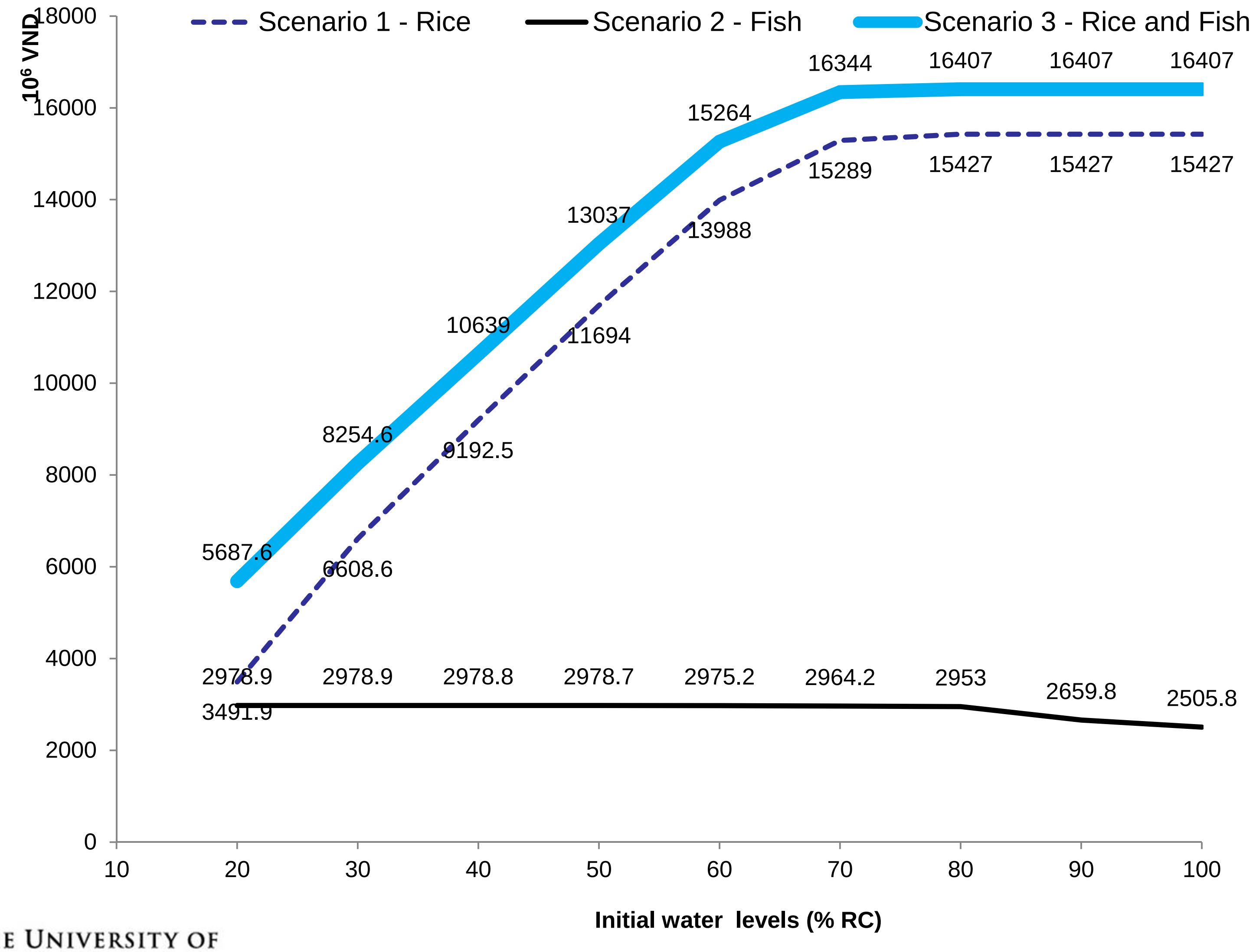
The expected net present value of the profits



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Comparing the outcomes of three scenarios

Scenarios	Maximum ENPV (mVND)[1]	Total release (MCM)
1. Rice	15,427	13.9
2. Fish	2,505	21
3. Rice and fish	16,407	21
+Rice	15,427	13.9
+Fish	980	7.1

[1] $A 1 = VND 20,000 (Price in January 2011)

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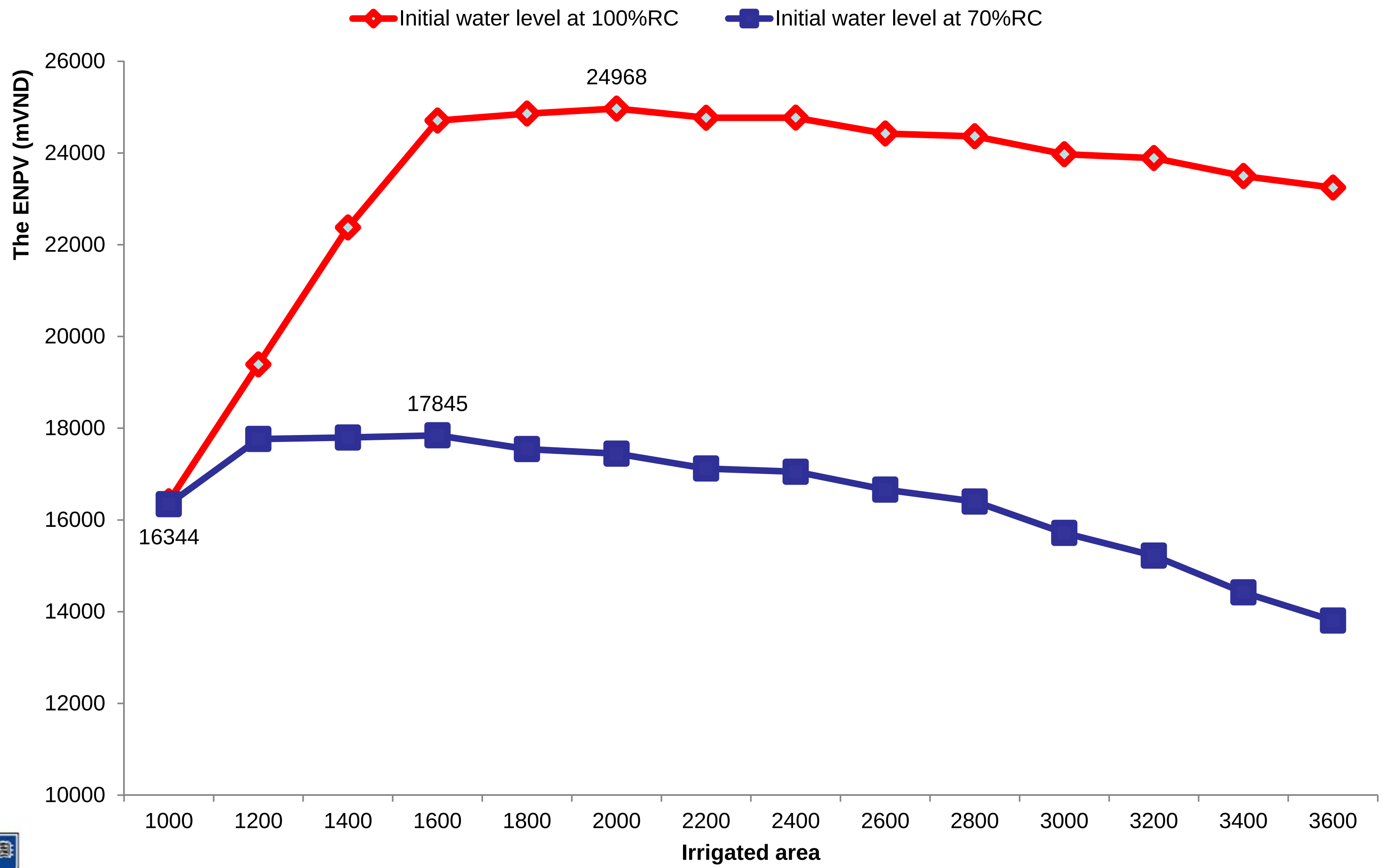
The possibility of extending the irrigated area



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IV. Conclusion

- Release strategy:

  ❖ Rice production

  - Adequate water should be released to satisfy CWR, residual water should be stored as a source of water for additional irrigation in case of drought

  ❖ Fish production

  - Maximum water should be released prior to fish harvest season

  ❖ Rice and Fish production

  - High initial water levels: Maximum water can be released prior to fish harvest season but residual water must be enough to satisfy the demand for rice for the remaining stages
  - Low initial water levels: Release give priority to rice production regardless of the demand for release for fish harvest

- The weather condition:

  - ❖ For rice production dry or wet year results in the same release strategy

  - ❖ For Fish, and Rice and Fish production: in a wet year much water is released compared with in a dry year