# Economic Optimization of Water

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# Introduction

- General Information on Irrigated Crops
- Economic Theory
  - Production Economics
- Related Study
- Data & Methods
- Preliminary Results
- What does it all mean?

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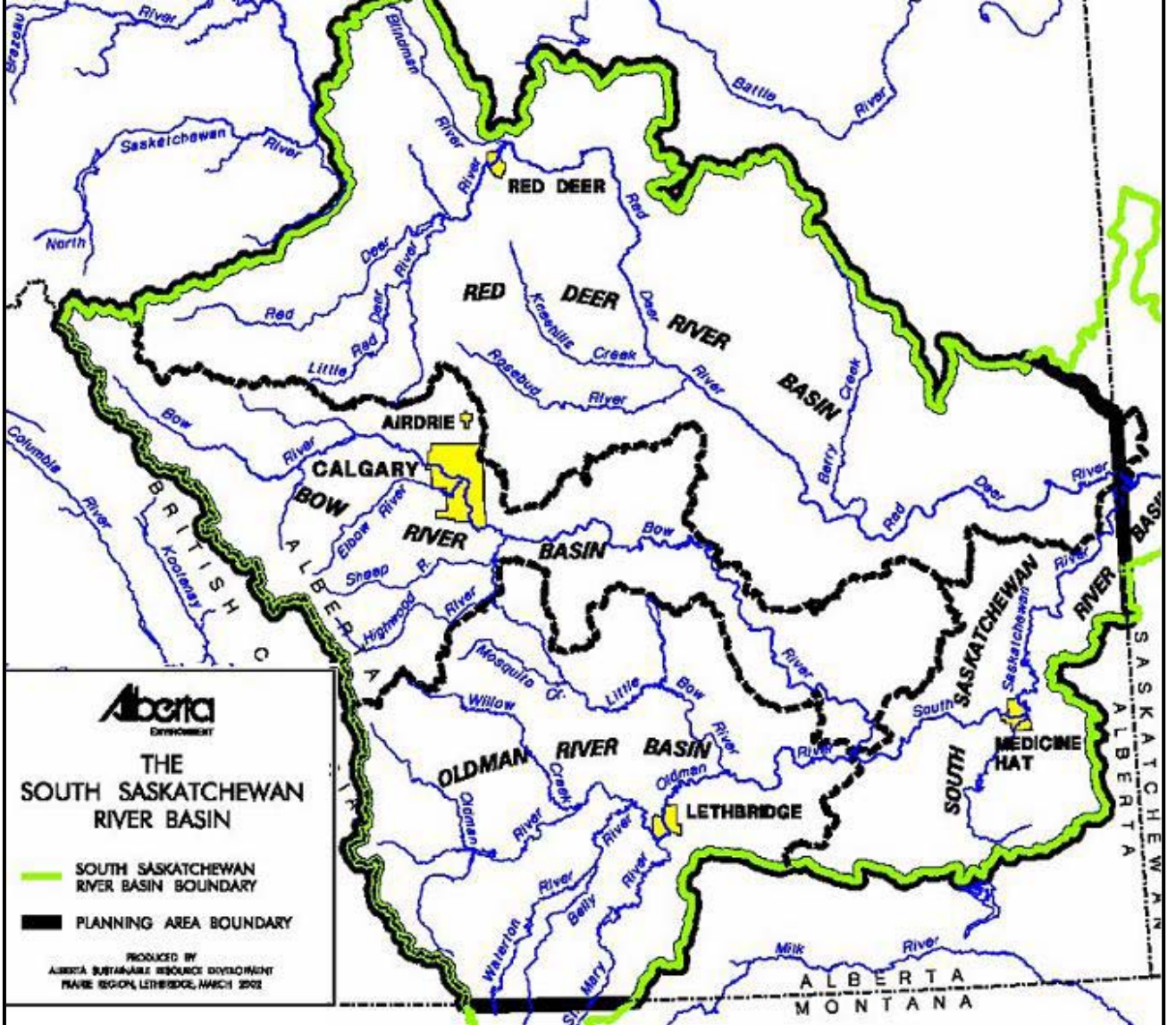
Alberta
ENVIRONMENT
THE
SOUTH SASKATCHEWAN
RIVER BASIN
SOUTH SASKATCHEWAN RIVER BASIN BOUNDARY
PLANNING AREA BOUNDARY
PRODUCED BY
ALBERTA SUSTAINABLE RESOURCE DEVELOPMENT
PRAIRIE REGION, LETHBRIDGE, MARCH 2002
RED DEER
AIRDRIE
CALGARY
LETHBRIDGE
MEDICINE HAT
RED DEER RIVER BASIN
BOW RIVER BASIN
OLDMAN RIVER BASIN
SOUTH SASKATCHEWAN RIVER
ALBERTA
SASKATCHEWAN
MONTANA
BRITISH COLUMBIA
Battle River
Saskatchewan River
North Saskatchewan River
Blindman River
Red Deer River
Little Red Deer River
Kneehills Creek
Rosebud River
Berry Creek
Bow River
Elbow River
Sheep R.
Highwood River
Mosquito Cr.
Willow Creek
Little Bow River
South Saskatchewan River
Oldman River
Oldman River
Waterton River
Belly River
St. Mary River
Milk River
Columbia River
Kootenay River
Brazeau River

# Irrigated crops in the SSRB

| | Acres | % of Total |
|---|---|---|
| **Cereals** | 408,586 | 30.5 |
| **Forages** | 607,514 | 45.3 |
| **Oil Seeds** | 128,044 | 9.6 |
| **Specialty Crops** | 169,155 | 12.6 |
| **Other** | 26,462 | 2.0 |

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# Cereals

| | |
|---|---|
| Barley | 167516 |
| CPS Wheat | 21597 |
| Durum | 63921 |
| Grain Corn | 1199 |
| Hard Spring Wheat | 95289 |
| Malt Barley | 1485 |
| Oats | 7341 |
| Rye | 1915 |
| Soft Wheat | 39489 |
| Winter Wheat | 8834 |

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# Forages

| | |
|---|---|
| Alfalfa - Two cuts | 68668 |
| Alfalfa - Three cuts | 3527 |
| Alfalfa Hay | 163507 |
| Alfalfa Silage | 10088 |
| Barley Silage | 83806 |
| Barley Silage (underseeded) | 2197 |
| Brome Hay | 2247 |
| Corn Silage | 37208 |
| Grass Hay | 31576 |
| Green Feed | 15456 |
| Milk Vetch | 368 |
| Native Pasture | 20828 |
| Oats Silage | 1612 |
| Sorghum/Sudan Grass | 454 |
| Tame Pasture | 117435 |
| Timothy Hay | 39169 |
| Tritcale Silage | 9368 |

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# Specialty Crops

| | |
|---|---|
| Alfalfa Seed | 10451 |
| Caraway Seed | 65 |
| Carrots | 1009 |
| Chick Peas | 1203 |
| Dill | 897 |
| Dry Beans | 48102 |
| Dry Peas | 8836 |
| Faba Beans | 703 |
| Fresh Corn (sweet) | 3973 |
| Fresh Peas | 4189 |
| Grass Seed | 3895 |
| Hemp | 451 |
| Lawn Turf | 2337 |
| Lentils | 62 |
| Market Gardens | 1064 |
| Mint | 1681 |
| Nursery | 2297 |
| Onions | 531 |
| Potatoes | 40519 |
| Safflower | 287 |
| Seed Potatoes | 576 |
| Small Fruit | 107 |
| Sugar Beets | 34993 |
| Sunflower | 927 |

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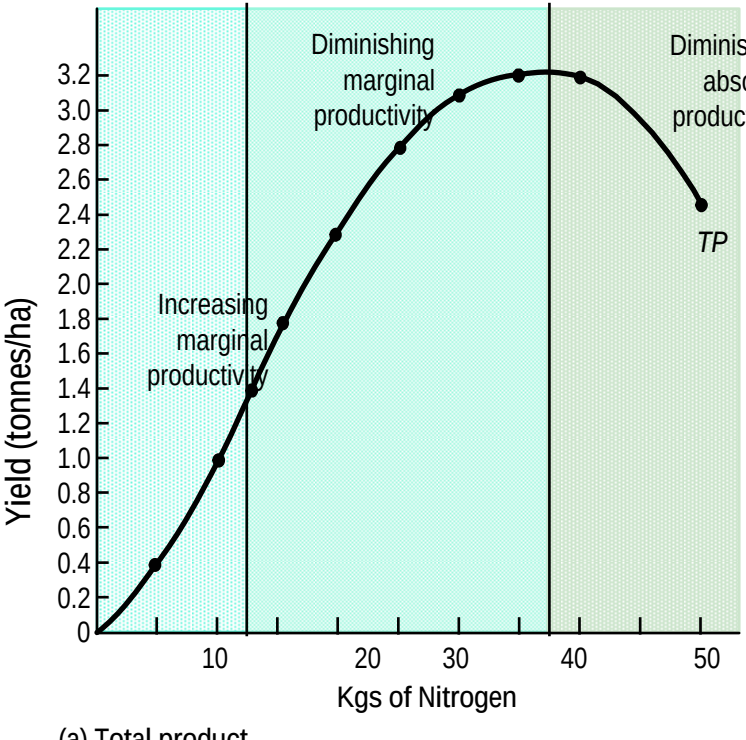
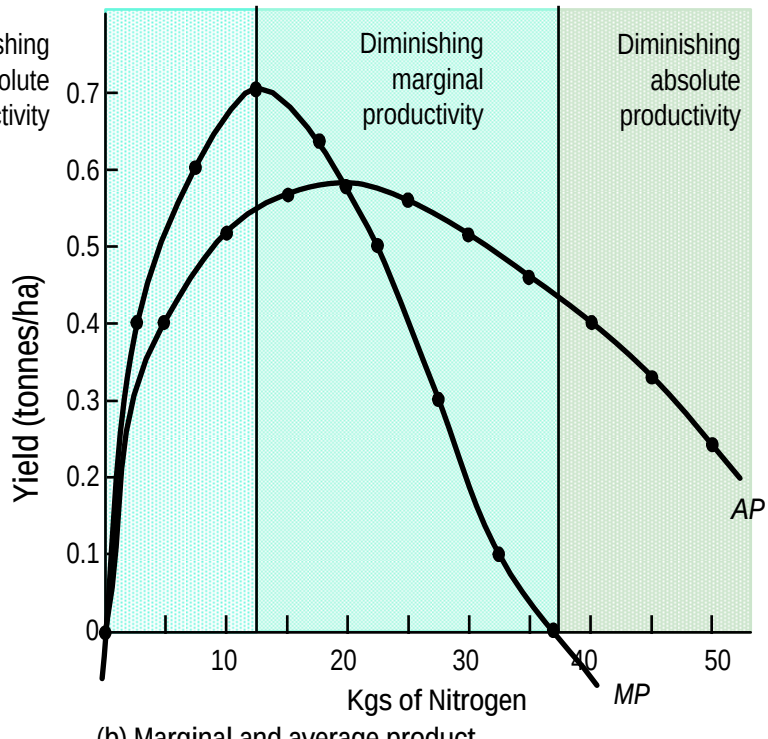
# Economic Theory

- Total Product and Marginal Product




(a) Total product




(b) Marginal and average product

# Economic Theory (2)

- P x MP = VMP = the increased returns from an increase in the input choice level
- BEST APPLICATION CHOICE
  - Where VMP = input price
- Importance of *ceteris paribus*

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# Related Research

- Economic Value of Water in Alternative Uses in the SSRB (Prairie Provinces Water Board – PPWB)
  - by Samarawickrema & Kulshreshtha (2005)
  - Used a yield response function (Heikkila et al 2002)
  - Prices were average 10 year – nominal prices
    - Net of labour, repair, maintenance and energy costs

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# Table 1a: Marginal Value Product ($/acre inch)

| Sub-Basin | Alfalfa | Barley | Barley Silage | Canola | Dry Beans |
|---|---|---|---|---|---|
| Bow | 20.15 | 13.16 | 11.41 | 11.51 | 66.20 |
| Oldman | 19.43 | 13.47 | 11.72 | 11.92 | 67.64 |
| Red Deer | 19.02 | 13.26 | 11.62 | 11.72 | 67.43 |
| SSRB - AB | 19.02 | 13.26 | 11.62 | 11.62 | 68.05 |
| SSRB-SK | 14.49 | 18.60 | 12.13 | 14.39 | 67.94 |

Source: The Prairie Provinces Water Board

# Table 1b: Marginal Value Product ($/acre inch)

| Sub-Basin | Tame Grass | HRS Wheat | SWS Wheat | Potato | Sugar Beet |
|---|---|---|---|---|---|
| Bow | 16.45 | 9.56 | 15.11 | 114.51 | 28.99 |
| Oldman | 17.37 | 9.66 | 15.52 | 118.52 | 29.81 |
| Red Deer | 16.96 | 9.66 | 15.32 | 117.28 | 29.81 |
| SSRB - AB | 16.75 | 9.66 | 15.32 | 116.46 | 29.40 |
| SSRB-SK | 16.34 | 9.87 | 15.52 | 112.45 | |

Source: The Prairie Provinces Water Board

# Discussion

- Prairie Provinces Water Board results are estimated at point of estimated current usage
- Average Estimated Usage by Sub-Basin:

| Sub-Basin | Amount (inches) |
|---|---|
| Oldman | 16.78 |
| Bow | 22.52 |
| Red Deer | 21.61 |
| SSRB | 16.06 |

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# Data & Methods

- Bow River Irrigation District
- Linear Optimization Model that maximizes the total net income of agriculture in the district
  - Optimizes cropping patterns in the district
  - Cobb-Douglas yield response function
  - Water constraint used to estimate shadow values, i.e. VMP
  - Able to capture how the value changes as application rate changes
  - Results comparable to Prairie Provinces Water Board results
  - Source: Arbenser et al (2005)

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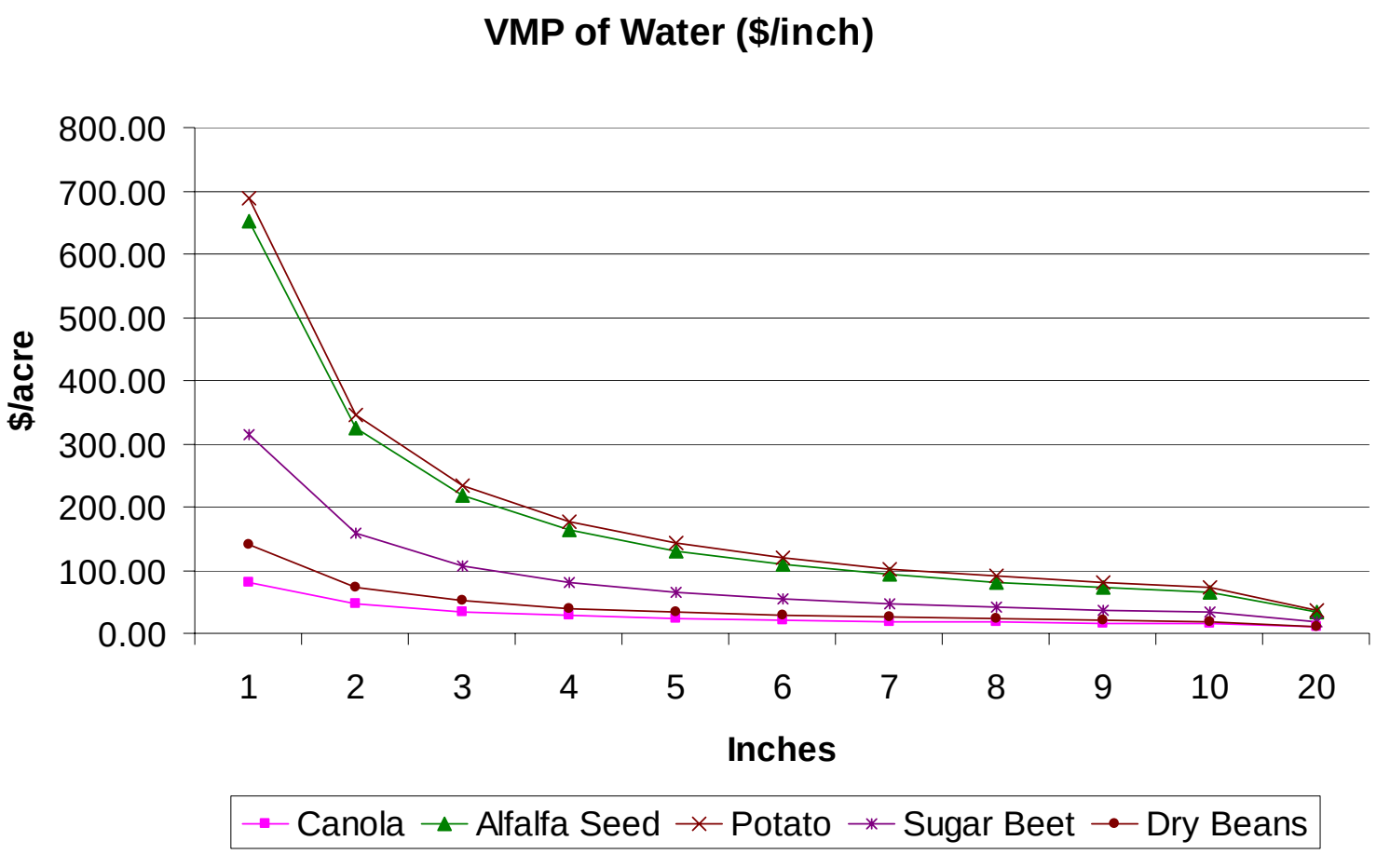
# Table 2a: Value of Water ($ per acre inch)

| Inches of Water | HRS Wheat | Durum Wheat | Malt Barley | Feed Barley | Alfalfa Hay | Flax |
|---|---|---|---|---|---|---|
| 1 | 90.94 | 30.49 | 87.41 | 159.11 | 136.01 | 80.92 |
| 2 | 52.79 | 19.79 | 44.98 | 79.77 | 76.02 | 46.09 |
| 3 | 39.79 | 16.01 | 30.73 | 53.28 | 55.68 | 34.20 |
| 4 | 33.10 | 14.00 | 23.54 | 40.01 | 45.31 | 28.07 |
| 5 | 28.97 | 12.70 | 19.18 | 32.04 | 38.94 | 24.28 |
| 6 | 26.12 | 11.77 | 16.24 | 26.71 | 34.59 | 21.66 |
| 7 | 24.02 | 11.05 | 14.12 | 22.90 | 31.40 | 19.73 |
| 8 | 22.39 | 10.48 | 12.52 | 20.03 | 28.95 | 18.23 |
| 9 | 21.08 | 10.01 | 11.26 | 17.80 | 27.00 | 17.03 |
| 10 | 20.00 | 9.60 | 10.24 | 16.01 | 25.40 | 16.03 |
| 20 | 14.42 | 7.31 | 5.47 | 7.90 | 17.40 | 10.95 |
| Optimal | 14.91 | 7.53 | 6.86 | 22.85 | 15.21 | 13.49 |
| PPWB (avg) | 9.68 | n/a | n/a | 14.35 | 18.42 | n/a |

# Table 2b: Value of Water ($ per acre inch)

| Inches of Water | Canola | Alfalfa Seed | Potato | Sugar Beet | Dry Beans |
|---|---|---|---|---|---|
| 1 | 80.55 | 651.57 | 687.51 | 314.29 | 140.36 |
| 2 | 45.52 | 325.97 | 346.69 | 158.61 | 73.95 |
| 3 | 33.59 | 217.41 | 232.91 | 106.61 | 51.57 |
| 4 | 27.47 | 163.12 | 175.90 | 80.54 | 40.23 |
| 5 | 23.68 | 130.53 | 141.62 | 64.85 | 33.32 |
| 6 | 21.08 | 108.79 | 118.71 | 54.36 | 28.65 |
| 7 | 19.16 | 93.26 | 102.30 | 46.84 | 25.26 |
| 8 | 17.68 | 81.61 | 89.97 | 41.18 | 22.67 |
| 9 | 16.49 | 72.54 | 80.34 | 36.77 | 20.64 |
| 10 | 15.51 | 65.28 | 72.63 | 33.23 | 18.98 |
| 20 | 10.53 | 32.57 | 37.50 | 17.07 | 11.06 |
| Optimal | 10.86 | 76.64 | 34.68 | 16.29 | 11.07 |
| PPWB (avg) | 12.23 | n/a | 115.84 | 29.5 | 67.45 |


VMP of Water ($/inch)
$/acre
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
1
2
3
4
5
6
7
8
9
10
20
Inches
Canola
Alfalfa Seed
Potato
Sugar Beet
Dry Beans

# Discussion (2)

- From PPWB we see that estimated values for water are fairly close across sub-basins for individual cops
- Values vary significantly across crops
- Values are fairly high – but it is assumed that other costs don't change when water is limited
- Values vary significantly with the amount applied

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# Concluding Comments

- Complexity of Estimating Value
  - And what about timing?
- Would be very important information with water markets
- Can get a rough idea if you know yield response functions
- Research needed in this area
- Questions?

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