Multi-air pollutant impacts on forage yields: A case study of alfalfa responses in West Central Alberta, Canada

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- Alberta is the single largest producer of oil and natural gas combined in N. America

- Of interest are the emissions of SO_x, NO_x, hydrocarbons and related organic compounds and PM

- Secondary pollutants include O_3 and fine particles

- Of concern to forage production for animals are: the direct effects of SO_2, NO_x and O_3 and their joint impacts with growth-regulating climate variables such as air temperature and precipitation

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As opposed to the traditional view of examining each pollutant source separately, application of the concept of air-shed management is to treat the combined emissions from all sources within the air shed contributing to the nature of the regional scale air mass and the interactions of that air mass with the air quality of the surrounding regions

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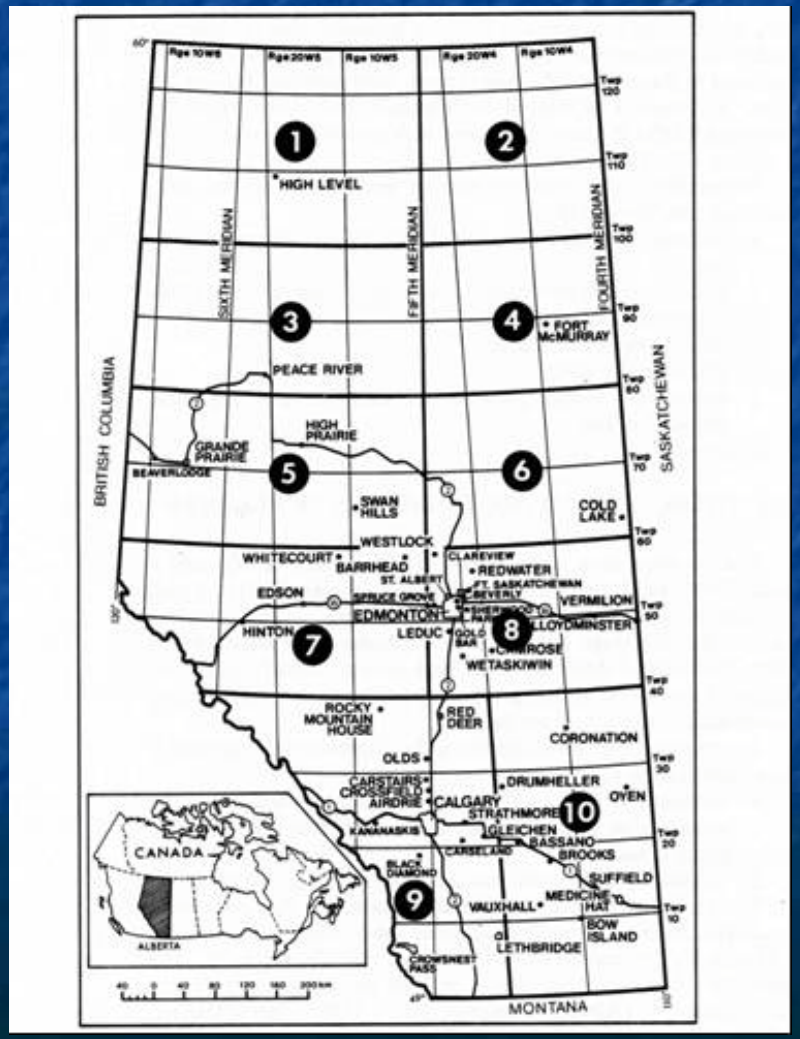

Town of Drayton Valley, AB

GPS Coordinates - N: 53.12506, W: 114.75104.

Pop: 6,000; Elevation: 870 m (ASL)

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- Members of the Program Board of Directors (represented by all sectors, government, private and public) concluded at the outset that:

- Any air quality impact assessments must be immediately relevant to ambient conditions in the study region and therefore, no artificial or experimental field exposures were to be used

- Equally importantly, plant cultural practices were to be identical to those of the agricultural community in the region

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- Under ambient conditions, the dynamics of multi-air pollutant exposures and chronic crop (yield) responses are stochastic by their nature

- However, virtually all our knowledge of that subject is based on univariate studies in artificial field exposures

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Study Summary

Study period:	5 years or growing seasons
Crop rotation cycle:	5 years
Number of harvests/year:	2
Crop age classes:	2-5 years
Total number of treatments (5 years):	78
AP-induced foliar injury:	Not detected

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Summary of hourly air pollutant and climate data (1998-2002), All sites combined

Variable	Minimum	Maximum
SO_2 (ppb)	< DL*	52
O_3 (ppb)	< DL*	97
O_3 (ppb)	<DL*	82
GSR (W/m^{2**})	0	1440
Temp. (^oC)	-18	34
RH (%)	13	99
Precip. (mm)	280	320

*DL = Detection Limit; ** Global Solar Radiation, only for hrs with GSR ≥ 50 W/m2)

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Data from all study sites, years and the two harvests/year combined:

Harvest # 1 yield > median value:	60%
Harvest # 2 yield > median value:	30% (+17 to +118%)
Harvest # 1 yield < median value:	40%
Harvest # 2 yield <median value:	70% (-15 to -83%)

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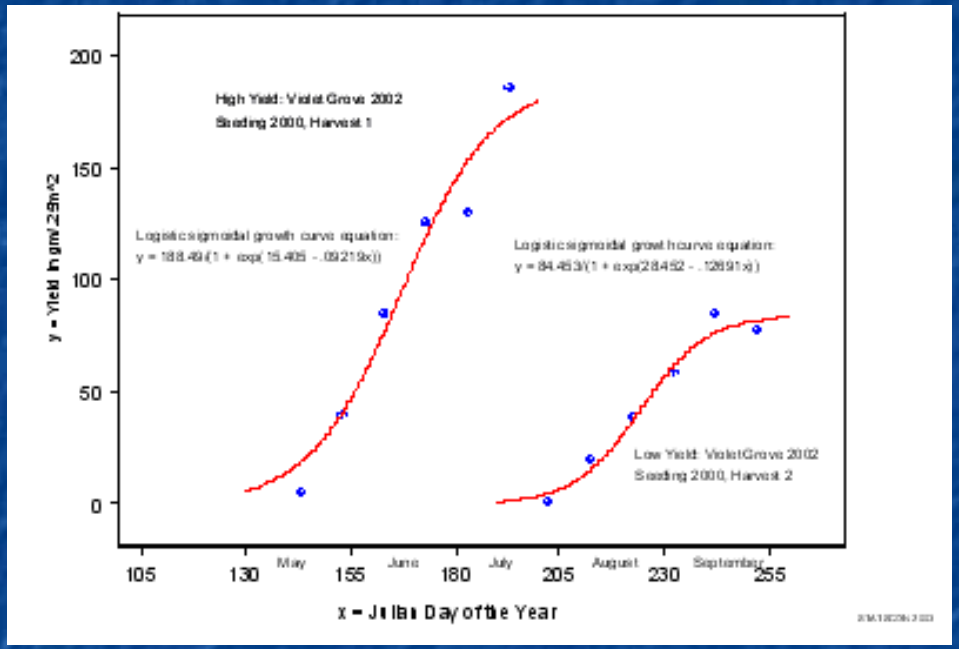

$$y = a/(1+\exp(b-cx))$$

Where:

y = the plant yield (in gm/0.25 m2)
x = the time in Julian days since the beginning of the year
a, b and c = model parameters

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ALFALFA YIELD VS. ALL PREDICTORS

Nomenclature (Examples):

O_3 p95_1 = Hourly O_3 concentration 95th percentile during alfalfa growth stage # 1

SO_2 _3 = Integral (concentration X duration) of SO_2 exposures during alfalfa growth stage # 3, NO_x exposures are also defined as an “integral”.

All others are average values, except precipitation in totals.

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Hybrid empirical-mechanistic time series model of cause and effect

$$Y_I = \beta_0 + \sum_{i=1}^{n} \beta_j X_{ij} + \varepsilon_{ij}$$

Where:

Y_i = Alfalfa yield by harvest or case #

X_{ij} = Value of predictor j for the case #

ε_{ij} = Error associated with the case and predictor j

Predictor selection: Best regression X Mallow's Critical Point (Cp)

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Alfalfa = 5260 – 14.7 O_3 med_1 + 7.85 O_3 p95_1 – 75.8 O_3 med_2 + 36.0 O_3 p95_2 + 89.7 O_3 med_3 –O_3 p95_3 + 0.565 SO_2 _1 – 0.115 NO_x_1 – 41.8 T_1 + 16.0 RH_1 + 2.35 GSR_1 + 0.483 SO_2 _2 + 0.125 NO_x_2 + 22.4 T_2 – 53.2 RH_2 – 3.94 GSR_2 + 0.160 SO_2 _3 + 0.217NO_x_3 – 140 T_3 – 5.3 RH_3 – 1.83 GSR_3 – 5.05 Precip_1

R^2 = 77.0%, R^2 (adj) = 67.7%, p = 0.000

% Contribution to R^2 by category

Ozone:	25.5
Sulfur dioxide + Oxides of nitrogen:	25.0
Climate:	26.7
Other:	22.8

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Model's Predictive Capacity of Yield:

(Results of Discriminant or Classification Analysis)

High yield (> Median value): 92%

Low yield (< Median value): 88%

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Conclusion

There is a critical need for multi-variant ambient studies, as opposed to the continued reliance on univariate controlled exposure experiments and incomplete definition of the crop response surface