# Virtual Soil Testing – What Is It?

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## Introduction

Currently only ten percent of the total arable land in western Canada is soil tested at best. The percentage of farmers that soil test on a yearly basis is even lower. Providing recommendations to the farming community for the non-tested land presents both a challenge and an opportunity. Virtual soil testing started as an idea to essentially utilize information collected from soil tested fields and provide more qualified recommendations for those fields that were not tested. Virtual soil testing (or VST®) is in essence a modeling technique that reverses the soil testing process, i.e., utilizes crop production characteristics in association with chemical tests to predict soil nutrient levels for a subsequent crop (Karamanos and Cannon 2002). It is based on the Fertility Analysis and Recommendations Management (F.A.R.M.) model (Kruger et al. 1994) that was developed by Henry (1990; 1991) and was subsequently adapted to Saskatchewan, Manitoba and Alberta conditions by Karamanos and Henry (1991) and Karamanos et al. (1992a,b), respectively.

F.A.R.M. essentially recognizes three sources of nitrogen contributing to plant N uptake, namely, soil available as determined by soil testing, net mineralizable and fertilizer nitrogen. Target yields are based on moisture use efficiency crop production equations (Karamanos and Henry, 1991) and are estimated for 75, 50 and 25 percent probability of precipitation in a given Soil Climatic Zone (Meyers and Karamanos, 1997). Recommendations for the rest of nutrients are simply based on "available" nutrient ranges and are in table format. This system of recommendations was introduced in the Province of Saskatchewan in 1991 and is currently used by Enviro-Test Laboratories in all three Prairie Provinces. Development of the VST process required modifications in the F.A.R.M. model, especially in relation to the soil mineralization component. These modifications are discussed by Karamanos and Cannon (2002).

## Materials and Methods

### Deriving Virtual Soil Tests For Nitrogen

The reverse soil testing process (Figure 1) was employed to the benchmark sites established by Alberta Agriculture in various locations across the province of Alberta (Cannon and Leskiw, 1999). These sites are geographically spread across the agricultural area of the Province of Alberta. Soil samples to assess the fertility status of each site are taken every fall from geo-referenced positions within each of three landscape positions. Only the sites with barley, wheat and canola in rotation were utilized. Soil test levels for nitrogen obtained in the fall of 1998 formed the basis of prediction of soil test levels for the fall of 1999 and actual and predicted soil test levels for 1999 formed the basis soil test levels for the fall of 2000.

# VST® PROCESS

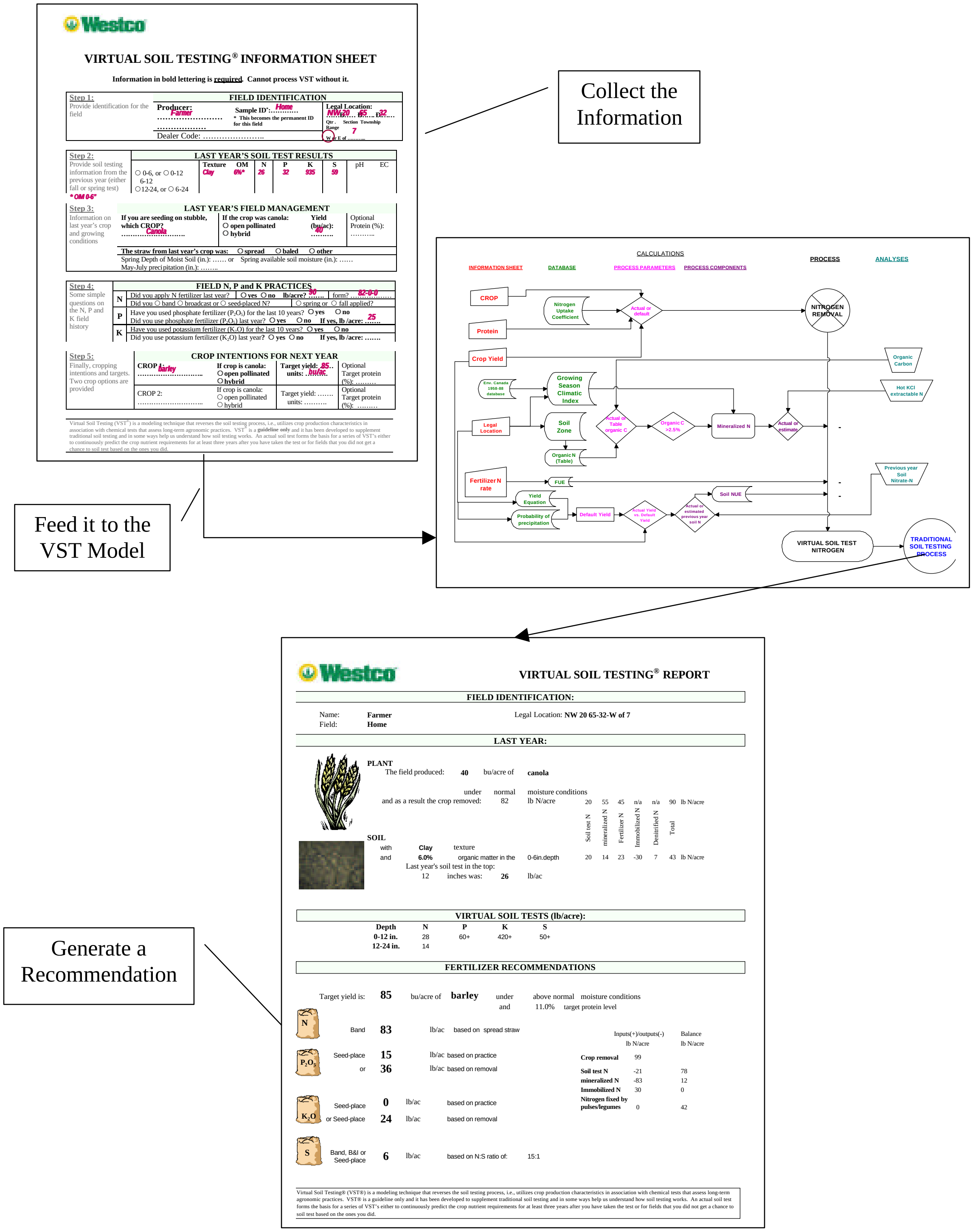


Figure 1. VST Process

**Deriving Nitrogen Recommendations**

To assess the ability of VST to predict crop requirements that are within the recommendations generated by laboratories operating in western Canada, samples from four experimental sites in 2000 and three in 2001 were collected, dried and split into six sub-samples using a riffle splitter. They were then submitted to six different laboratories operating in the region (Tables 1, 2 and 3). Experimental techniques were those described by Karamanos and Cannon (2002). P recommendations were based on previous history and included three rates, namely, 15, 30 and 45 kg $P_2O_5$ $ha^{-1}$ depending on whether past P fertilization history was excessive, normal or very poor, respectively. Potassium recommendations were based on general trends obtained by summarizing a large number of experiments from the WESTCO database (Karamanos et al. 2000) and sulphur recommendations on optimum N:S ratios (e.g., 6:1 for canola and 17:1 for wheat).

Table 1. Mean, high and low values of the soil testing parameters determined in the 2000 and 2001 field experiments.

| | | **OM** | **N** | **P** | **K** | **S** | **Cu** | **Mn** | **Zn** | **B** | **Fe** | **Cl** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Parameter** | % | ppm | | | | | | | | | |
| | | | | | 2000 | | | | | | | |
| Allan, SK | Mean | 2.7 | 6 | 15 | 383 | 18 | 1.0 | 18 | 1.2 | .8 | 53 | 7 |
| | High | 3.1 | 8.5 | 18 | 450 | 52 | 1.2 | 26 | 1.3 | 1.1 | 62 | 13 |
| | Low | 2.3 | 3 | 11 | 300 | 4 | 0.9 | 9 | 1.0 | 0.4 | 42 | 3 |
| Ft. Sask., AB | Mean | 6.5 | 21 | 9 | 174 | 13 | 0.7 | 12 | 2.4 | 1.3 | 93 | 26 |
| | High | 8.4 | 23 | 11 | 220 | 24 | 0.9 | 18 | 3.1 | 1.9 | 116 | 40 |
| | Low | 5.0 | 18 | 8 | 150 | 6 | 0.6 | 5 | 1.9 | 0.5 | 66 | 6 |
| Irricana, AB | Mean | 3.1 | 5 | 16 | 287 | 10 | 0.9 | 28 | 2.1 | 0.6 | 80 | 8 |
| | High | 4.0 | 6 | 20 | 300 | 20 | 1.4 | 36 | 2.4 | 1.0 | 94 | 12 |
| | Low | 1.0 | 3 | 12 | 240 | 5 | 0.7 | 18 | 1.8 | 0.2 | 56 | 4 |
| Rosser, MB | Mean | 4.9 | 15 | 33 | 511 | 21 | 2.3 | 6 | 1.4 | 1.7 | 45 | 13 |
| | High | 6.1 | 22 | 42 | 696 | 42 | 3.5 | 11 | 2.2 | 4.1 | 62 | 20 |
| | Low | 3.7 | 11 | 27 | 300 | 7 | 0.1 | 2 | 0.3 | 0.5 | 15 | 8 |
| | | | | | 2001 | | | | | | | |
| Red Deer, AB | Mean | 7.1 | 8 | 8 | 238 | 8 | 0.6 | 7 | 2.0 | 0.9 | 29 | 17 |
| | High | 9.9 | 12 | 15 | 264 | 12 | 0.8 | 10 | 2.4 | 1.2 | 34 | 22 |
| | Low | 5.0 | 6 | 4 | 197 | 4 | 0.6 | 4 | 1.7 | 0.7 | 24 | 14 |
| Balzac, AB | Mean | 5.6 | 11 | 15 | 227 | 9 | 0.5 | 7 | 1.5 | 0.6 | 33 | 6 |
| | High | 10.6 | 14 | 18 | 250 | 13 | 0.6 | 10 | 1.7 | 0.9 | 40 | 12 |
| | Low | 4.0 | 9 | 11 | 208 | 5 | 0.3 | 4 | 1.3 | 0.4 | 27 | 3 |
| Ellerslie, AB | Mean | 8.1 | 13 | 16 | 188 | 13 | 1.0 | 6 | 5.2 | 1.9 | 94 | 17 |
| | High | 10.7 | 17 | 20 | 220 | 25 | 1.2 | 12 | 6.3 | 2.8 | 116 | 24 |
| | Low | 6.1 | 10 | 10 | 166 | 5 | 0.8 | 3 | 4.7 | 1.2 | 80 | 14 |

Table 2. Recommendations from each laboratory for growing wheat (lb/acre).

| Lab. | Allan N-P-K-S Cu-Zn-Mn-B | Irricana N-P-K-S Cu-Zn-Mn-B | Ft. Saskatchewan N-P-K-S Cu-Zn-Mn-B | Rosser N-P-K-S Cu-Zn-Mn-B | Red Deer N-P-K-S Cu-Zn-Mn-B | Balzac N-P-K-S Cu-Zn-Mn-B | Ellerslie N-P-K-S Cu-Zn-Mn-B |
|---|---|---|---|---|---|---|---|
| A | 50-30-20-0<br>0-0-0-0 | 60-20-0-0<br>0-0-0-0 | 0-30-15-0<br>0-0-0-0 | 60-20-15-0<br>0-0-0-0 | 70-43-15-7<br>3.5-0-0-0 | 65-23-15-0<br>3.5-0-0-0 | 50-23-10-0<br>0-0-0-0 |
| B | 60-30-15-8<br>0-0-0-0 | 65-20-0-0<br>0-0-0-0 | 5-30-15-5<br>0-0-0-0 | 45-20-15-0<br>0-0-0-0 | 116-32-10-5<br>2-0-0-0 | 87-21-10-5<br>3-0-0-0 | 110-15-10-5<br>1-0-0-0 |
| C | 50-22-0-0<br>0-0-0-0 | 55-20-0-0<br>0-0-0-0 | 0-34-15-0<br>0-0-0-0 | 40-13-0-0<br>0-0-0-0 | 110-32-19-10<br>1-0-0-0 | 68-24-0-0<br>1-0-0-0 | 109-32-0-0<br>0-0-0-0 |
| D | 60-21-0-5<br>0-0-0-0 | 60-23-0-4<br>0-0-0-0 | 0-30-0-0<br>0-0-0-0 | 28-10-0-0<br>0-0-0-0 | 75-43-15-7.5<br>0-0-0-0 | 90-23-0-0<br>3.5-0-0-0 | 75-28-10-0<br>0-0-0-0 |
| E | 110-30-10-0<br>1-0-0-1 | 129-24-25-0<br>1-0-0-1 | 50-30-25-0<br>1-0-0-1 | 120-20-10-0<br>0-0-0-0 | 93-45-0-10<br>1-0-0-0 | 56-25-0-0<br>3-0-0-0 | 85-26-19-0<br>0-0-0-0 |
| F | 110-20-0-12<br>1.6-0-1.2-1 | 110-20-10-14<br>3-0-0-0 | 70-40-40-12<br>3.5-1-0-0 | 75-0-0-5<br>3.5-2-2.4-0 | 95-30-25-14<br>3.5-1.6-0.1-0 | 70-15-25-12<br>3.2-1.3-0.6-0 | 80-10-35-8<br>2-1.8-0-0 |
| VST | 75-25-15-8<br>0-0-0-0 | 78-22-15-7<br>0-0-0-0 | 34-20-15-7<br>0-0-0-0 | 50-20-15<br>0-0-0-0-0 | 82-25-15-0<br>0-0-0-0 | 80-25-15-0<br>0-0-0-0 | 70-25-15-0<br>0-0-0-0 |
| Local | | | | | 80-28-0-0<br>0-0-0-0 | 65-25-10-5<br>0-0-0-0 | 65-25-10-10<br>0-0-0-0 |

Table 3. Recommendations from each laboratory for growing canola (lb/acre).

| Lab. | Allan N-P-K-S-Cu-Zn-Mn-B | Irricana N-P-K-S-Cu-Zn-Mn-B | Ft. Saskatchewan N-P-K-S-Cu-Zn-Mn-B | Rosser N-P-K-S-Cu-Zn-Mn-B | Balzac N-P-K-S-Cu-Zn-Mn-B | Ellerslie N-P-K-S-Cu-Zn-Mn-B |
|---|---|---|---|---|---|---|
| A | 45-30-0-80-0-0-0-0 | 55-20-19-12-0-0-0-0 | 7-30-0-8-0-0-0-0 | 75-20-0-12-0-0-0-0 | 75-23-15-13-0-0-0-0.5 | 80-23-10-13-0-0-0-0 |
| B | 55-30-0-12-0-0-0-0 | 60-20-0-8-0-0-0-0 | 20-30-10-12-0-0-0-0 | 60-20-0-12-0-0-0-0 | 88-24-0-15-1-0-0-2 | 119-13-0-15-0-0-0-0 |
| C | 75-20-0-0-0-0-0-0 | 63-17-0-15-0-0-0-0 | 0-31-0-0-0-0-0-0 | 62-12-0-0-0-0-0-0 | 74-25-0-24-0-0-0-1 | 95-35-0-24-0-0-0-0 |
| D | 74-25-0-15-0-0-0-0 | 77-23-0-22-0-0-0-0 | 0-34-0-0-0-0-0-0 | 42-13-0-0-0-0-0-0 | 100-23-0-18-0-0-0-0 | 105-28-10-13-0-0-0-0 |
| E | 120-30-0-20-1-0-0-1 | 120-25-0-20-0-0-0-2 | 72-30-0-15-0-0-0-2 | 120-30-0-20-0-0-0-0 | 63-26-0-15-3-0-0-0 | 69-29-23-30-0-0-0-0 |
| F | 110-30-0-21-0-2.1-0-0 | 105-30-0-23-0.9-0-0-0 | 65-50-40-21-1-1.6-0-0 | 75-0-0-8-1.8-4-3.3-0 | 75-25-15-21-1.1-2.3-1-0 | 90-15-30-15-0-3.3-0-0 |
| VST | 70-20-0-10-0-0-0-0 | 80-22-0-11-0-0-0-0 | 50-20-0-20-0-0-0-0 | 65-20-0-9-0-0-0-0 | 85-20-0-11-0-0-0-0 | 85-20-0-12-0-0-0-0 |
| Local | | | | | 80-25-10-10-0-0-0-0 | 75-25-10-20-0-0-0-0 |

All data were subject to Basic Statistics or Analysis of Variance as appropriate using SYSTAT 8.0 (SPSS Inc. 1998). The 95% Control limits were used to demonstrate the variance among laboratories. Revenue less fertilizer input expenses (RLFE) in CAN$ $ha^{-1}$ were calculated for the 2000 data, based on commodity (adjusted for protein premiums) and fertilizer prices in the spring of 2000.

## Results and Discussion

### Virtual Soil Tests For Nitrogen

Predicted values for the fall 1999 soil tests for the Alberta Agriculture benchmark sites were based either on Organic Carbon or on hot KCl values to estimate soil mineralized N. The correlation was stronger when predictions were based on organic carbon data rather than hot KCl $NH_4$-N (Figure 1). The fall 2000 predicted values were compared to the actual 2000 soil test N levels (Figure 2).

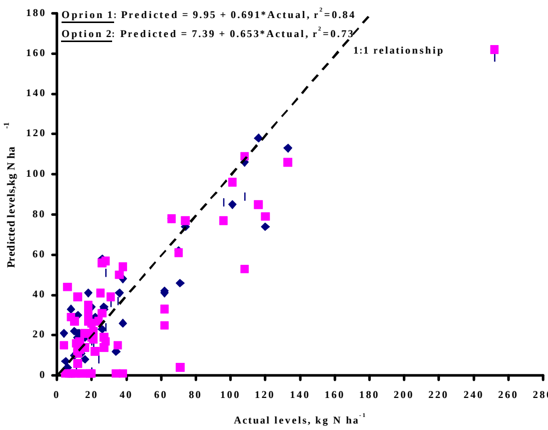


Figure 2. Relationship between fall 1999 predicted and actual soil test nitrogen levels based either on organic carbon (◆) or hot KCl NH4-N (■) levels.

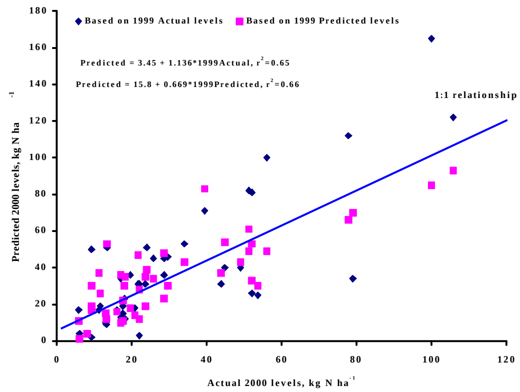


Figure 3. Relationship between fall 2000 predicted soil test nitrogen levels based either on actual fall 1999 (◆) or predicted fall 1999 (■) levels and actual fall 2000 nitrogen levels.

The correlation was similar for prediction based either on actual or predicted 1999 fall data, however, it was not as strong as in 1999.

### Recommendations Using Virtual Soil Testing

There was a significant effect of the recommendation package on the yield of hard red spring wheat and canola in all but one case (Tables 4 and 5). Recommendations based on virtual soil testing resulted in maximum yield in nine of the thirteen experiments and in maximum revenue less fertilizer input expenses (RLFE) in six of the eight experiments.

The conditions at the Rosser site were unusual, since the site received 350 mm of rain during the growing season. This made the site unapproachable for any herbicide or fungicide applications and the unusually high nitrogen recommendation by one of the Laboratories resulted both in greater yields of wheat and canola and greater revenue less fertilizer input expenses (RLFE).

The RLFE for virtual soil testing at the remaining sites was statistically the same with the maximum RLFE received at each site.

Table 5. The effect of laboratory recommendation on yield (kg $ha^{-1}$), crude protein content (% crude protein) of hard red spring wheat and revenue less fertilizer input expenses (RLFE – CAN$ $ha^{-1}$) of hard red spring wheat grown in 2000.

| Site | Parameter | VST | LAB A | LAB B | LAB C | LAB D | LAB E | LAB F | *Local* | *(P)* [a] |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Irricana, AB*** | Yield | 3810 a | 3494 c | 3655 abc | 3474 c | 3588 bc | 3756 ab | 3743 ab | | ** |
| | Protein | 15.5 ab | 15.5 ab | 14.8 b | 14.6 b | 14.7 b | 17.1 a | 17.3 a | | ** |
| | RLFE | 581 a | 509 a | 555 a | 534 a | 538 a | 529 a | 521 a | | |
| ***Fort*** | Yield | 4509 bc | 3400 d | 3810 d | 3675 d | 3649 d | 4616 ab | 4986 a | | ** |
| ***Saskatchewan,*** | Protein | 13.0 ab | 11.5 bc | 12.0 bc | 11.2 c | 12.2 bc | 12.9 ab | 14.5 a | | ** |
| ***AB*** | RLFE | 614 a | 395 c | 475 c | 434 c | 478 c | 589 ab | 637 a | | ** |
| ***Allan, SK*** | Yield | 2164 a | 2090 a | 1949 a | 2096 a | 2063 a | 2083 a | 2029 a | | NS |
| | Protein | 14.5 a | 13.4 a | 11.7 a | 13.5 a | 11.7 a | 13.3 a | 13.3 a | | NS |
| | RLFE | 276 a | 283 a | 199 a | 285 a | 201 a | 225 a | 201 a | | NS |
| ***Rosser, MB*** | Yield | 1606 cd | 1774 c | 1579 cd | 1431 d | 1176 e | 2775 a | 1268 b | | ** |
| | Protein | 13.6 b | 14.1 b | 14.2 b | 14.7 b | 14.4 b | 16.5 a | 14.7 b | | ** |
| | RLFE | 185 bc | 211 b | 187 bc | 195 bc | 159c | 376 a | 209 bc | | ** |
| ***Red Deer, AB*** | Yield | 3924a | 3870a | 4059a | 3904a | 4052a | 3843a | 3951a | 3985a | **[c] |
| | Protein | 11.2bc | 10.5b | 12.3ac | 10.6b | 12.2ac | 10.0d | 11.5b | 10.5b | ** |
| ***Balzac, AB*** | Yield | 3696a | 3736a | 3904a | 3823a | 3763a | 3810a | 3857a | 3790a | ** |
| | Protein | 12.6bd | 12.0cd | 13.7a | 13.7ae | 12.2b | 13.1be | 13.3a | 12.9b | ** |
| ***Ellerslie, AB*** | Yield | 4186b | 3891bc | 4489ab | 4388ab | 4119b | 4361ab | 4341ab | 4139b | ** |
| | Protein | 12.2be | 11.4c | 13.3ad | 13.2ad | 12.1ce | 12.4b | 12.7bd | 12.2be | ** |

[a] ,  *, ** Significant at P  0.10, 0.05, and 0.01 respectively; NS, not significant .
[b] Values followed by the same letter are not significantly different using Tukey HSD ( P   0.05).
[c] Experiments in 2001 also included an absolute control, thus the significance.

Table 6. The effect of laboratory recommendation on yield (kg $ha^{-1}$) of canola, and oil content (% oil) and revenue less fertilizer input expenses (RLFE - CAN$ $ha^{-1}$) of canola grown in 2000.

| Site | Parameter | VST | LAB A | LAB B | LAB C | LAB D | LAB E | LAB F | *Local* | *(P)* [a] |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Irricana, AB*** | Yield | 2710 a | 2531 a | 2520 a | 2593 a | 2727 a | 2693 a | 2744 a | | * |
| | Oil Content | 46.6 ab | 46.8 ab | 47.1 a | 46.6 ab | 45.7 ab | 44.8 b | 44.9 ab | | ** |
| | RLFE | 714 a | 669 a | 653 a | 689 a | 712 a | 653 a | 685 a | | |
| ***Fort*** | Yield | 2413 a | 2217 ab | 2128 ab | 2290 ab | 2049 b | 2413 a | 2352 a | | ** |
| ***Saskatchewan,*** | Oil Content | 45.2 ab | 46.8 a | 46.6 ab | 45.0 ab | 46.4 ab | 44.5 b | 45.1 ab | | ** |
| ***AB*** | RLFE | 639 a | 607 ab | 568 ab | 633 ab | 565 ab | 611 ab | 556 b | | * |
| ***Allan, SK*** | Yield | 1719 cd | 1450 e | 1568 de | 1708 cd | 1797 c | 1971 ab | 2021 a | | ** |
| | Oil Content | 45.4 abc | 47.0 a | 45.9 ab | 45.6 abc | 45.1 abc | 43.9 bc | 43.4 c | | ** |
| | RLFE | 437 ab | 366 c | 392 bc | 438 ab | 450 a | 429 ab | 475 a | | ** |
| ***Rosser, MB*** | Yield | 1400 b | 1501 b | 1316 b | 1338 b | 1047 c | 2033 a | 1045 b | | ** |
| | Oil Content | 46.8 a | 47.8 a | 45.7 a | 47.2 a | 46.8 a | 45.7 a | 46.6 a | | NS |
| | RLFE | 348 bc | 369 b | 324bcd | 344 bc | 269 d | 486 a | 297 cd | | ** |
| ***Balzac, AB*** | Yield | 1585ac | 1579ac | 1646a | 1512ac | 1753a | 1495ac | 1607ac | 1456b | **[c] |
| ***Ellerslie, AB*** | Yield | 3696a | 3757a | 4032a | 3942a | 4088a | 3824a | 4043a | 3679a | ** |

[a]  , *, ** Significant at P  0.10, 0.05, and 0.01 respectively; NS, not significant .
[b] Values followed by the same letter are not significantly different using Tukey HSD ( P   0.05).
[c] Experiments in 2001 also included an absolute control, thus the significance.

## Conclusion

Reversing the steps in the soil testing process led to a reasonable estimate of fertilizer recommendations for common crops in western Canada. This mechanistic model presents an opportunity for western Canadian Soil Testing Laboratories to offer supplemental information for those fields that are not soil tested on a yearly basis.

## References


Cannon, K. and L. Leskiw. 1999. Soil quality benchmarks in Alberta. pp. 18-184. In: Proceedings 36th Annual Alberta Soil Science Workshop. Calgary, AB.

Henry, J.L. 1990. Development of crop water production functions for wheat barley and canola to revise nitrogen fertilizer recommendations in Saskatchewan. Mimeo Report Department of Soil Science, University of Saskatchewan, Saskatoon, SK.

Henry, J.L. 1991. Development of soil test based nitrogen fertilizer recommendations for wheat, barley, canola, flax and oats. Mimeo report, Department of Soil Science, University of Saskatchewan, Saskatoon, SK.

Karamanos, R.E. and Cannon, K.R. 2002. Virtual Soil Testing. Is it Possible? Comm. Soil Sci. Plant Anal. *(in press)*.

Karamanos, R.E. and J.L. Henry, 1991. Criteria for targeting yields in Saskatchewan. pp. 124-133. In: Economics of Prairie Agriculture in the 1990's. University of Saskatchewan, Saskatoon, Saskatchewan.

Karamanos, R.E., G.A. Kruger and J.L. Henry, 1992a. Application of Water-Use Efficiency Functions to Fertilizer Nitrogen Recommendations. pp. 189-193. In: Proceedings 29th Annual Alberta Soil Science Workshop, Lethbridge, Alberta.

Karamanos, R.E., G.A. Kruger and J.L. Henry, 1992b. Nitrogen Fertilizer Recommendations Based on Crop Water Use Efficiency Functions. pp. 220-229. In: Proceedings 35th Annual Manitoba Society of Soil Science Meeting, Winnipeg, Man.

Karamanos R.E., N.A. Flore and J.T. Harapiak. 2000. Application of Seed-Row Potash to Soils with High Available Potassium Levels. pp. 180-186. In: Proceedings of the 2000 Soils and Crops, University of Saskatchewan, Saskatoon, SK.

Kruger, G.A., R.E. Karamanos and J.L. Henry, 1994. Fertility Analysis and Recommendations Manager (F.A.R.M.). Comm. Soil Sci. Plant Anal. 25, 955-965.

Meyers P. and R.E. Karamanos, 1997. Soil climatic zones of the Canadian prairies. Pp. . In: Proceedings 34th Annual Alberta Soil Science Workshop, Edmonton, Alberta.

SPSS Inc. 1998. SYSTAT 8.0. Chicago, IL.