
Virtual Soil Testing – What Is It?

Rigas E. Karamanos¹ and Karen Cannon²

¹Western Cooperative Fertilizers Limited, ²Conservation and Development Branch, Alberta
Agriculture, Food and Rural Development

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

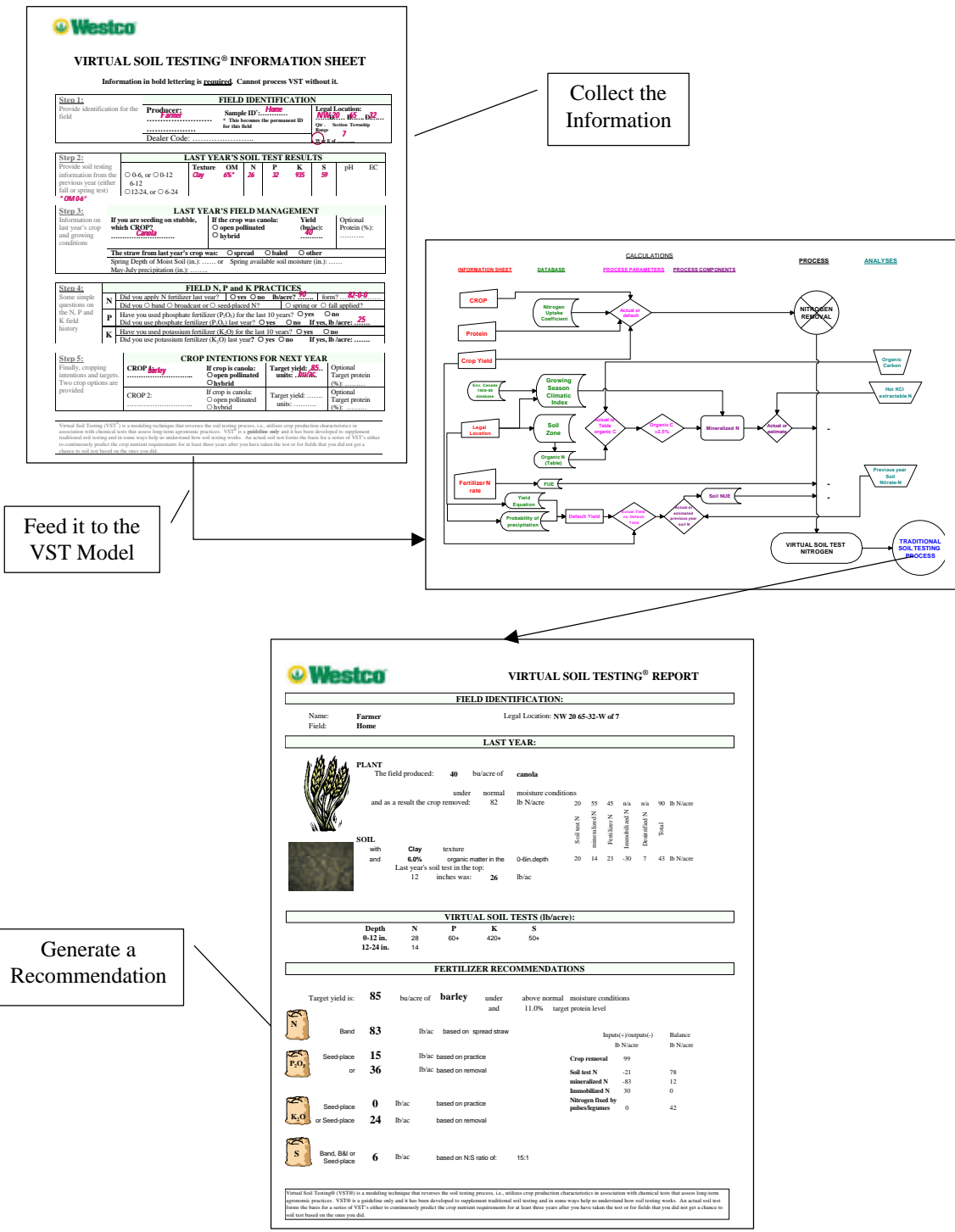


Figure 1. VST Process

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 P₂O₅ 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.

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

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

Lab.	Allan	Irricana	Ft. Saskatchewan	Rosser	Balzac	Ellerslie
	N-P-K-S-Cu-Zn-Mn-B	N-P-K-S-Cu-Zn-Mn-B	N-P-K-S-Cu-Zn-Mn-B	N-P-K-S-Cu-Zn-Mn-B	N-P-K-S-Cu-Zn-Mn-B	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 NH₄-N (Figure 1). The fall 2000 predicted values were compared to the actual 2000 soil test N levels (Figure 2).

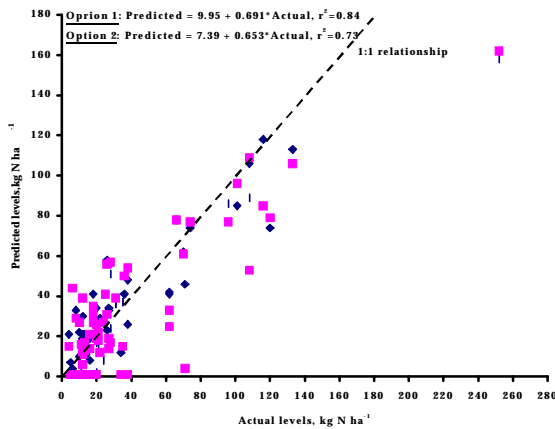


Figure 2. Relationship between fall 1999 predicted and actual soil test nitrogen levels based either on organic carbon (◆) or hot KCl NH₄-N (■) levels.

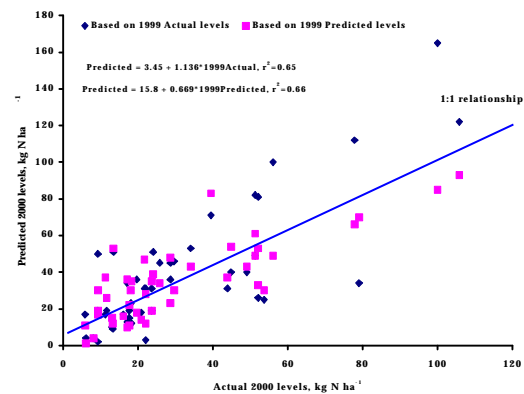


Figure 3. Relationship between fall 2000 predicted soil test nitrogen levels based either on actual fall 1999 (◆) or predicted fall 1999 (■) levels and actual fall 2000 nitrogen levels.

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 Saskatchewan, AB	Yield	4509 bc	3400 d	3810 d	3675 d	3649 d	4616 ab	4986 a		**
	Protein	13.0 ab	11.5 bc	12.0 bc	11.2 c	12.2 bc	12.9 ab	14.5 a		**
	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 Saskatchewan, AB	Yield	2413 a	2217 ab	2128 ab	2290 ab	2049 b	2413 a	2352 a		**
	Oil Content	45.2 ab	46.8 a	46.6 ab	45.0 ab	46.4 ab	44.5 b	45.1 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.

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