CONSIDER THE VALUE OF PLANT NUTRIENTS IN YOUR HAY AND CORN SILAGE

Glenn E. Shewmaker[1]

ABSTRACT

Alfalfa and corn silage are major crops in acreage and economic importance for the Pacific Northwest and are marketed for and used by dairy cows, beef cattle, and other livestock. With the large increases in fertilizer prices, the value of nutrients in a ton of hay or corn silage can no longer be considered insignificant! How many pounds of nutrients are you exporting? What is the cost to replace the major nutrients? This paper describes a process and uses some current values to determine the magnitudes, sustainability, and economics of nutrient export.
Keywords: nutrient uptake, nutrient export, alfalfa hay, corn silage, fertilizer prices

INTRODUCTION

There are published values for nutrient uptake and crop use of nutrients. You can download a document "Nutrients Removed in Harvested Portion of Crop" from International Plant Nutrition Institute (IPNI) (http://www.ipni.net/ International Plant Nutrition Institute, 2012). Although IPNI has some values, I wanted to use more local crops and concentrations and include sulfur (S) to estimate nutrient export and cost.

METHODS

I used a series of spreadsheets to generate data. Thus the results are "book values" and actual nutrient analyses of crops exported would provide more accurate results. However, the magnitudes of nutrients exported should be within 30% of these values. I focused this study on the macro-minerals nitrogen (N), phosphorus (expressed on the fertilizer analysis form of available phosphoric acid or phosphate, P_2O_5), potassium (expressed as the water soluble potash form, K_2O), and sulfur (S). Certainly other nutrients such as calcium (Ca), magnesium (Mg), and micro nutrients such as copper (Cu), zinc (Zn), manganese (Mn), etc. are also exported and will have to be replaced eventually. Replacement of some of the nutrients comes from the weathering or mineralization of soil particles, but the time required is long-term, and there is a limit to the soils ability to mineralize nutrients.

Nutrient Concentrations in Crops

I used a feed mineral table in a spreadsheet to generate the data:

Table 1 (Feed Mineral Table 2008.xls) uses selected feeds from Table 11-1 Means and SD for Composition Data of Feeds Commonly Used in Beef Cattle Diets, in the Nutrient Requirements of Beef Cattle, 2000, by the National Research Council. I have substituted some values from forage quality databases from University of Idaho research because they should be more reflective of actual soil, environmental, and agronomic management in Idaho.

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[1] G. Shewmaker, University of Idaho Kimberly R&E Center, 3608 N 3600 E, Kimberly, ID 83341. Published **In**: Proceedings, Idaho Hay and Forage Conference 1-2 March 2012, Burley, ID, University of Idaho Extension.

Nutrients Removed in Crops

Table 2 (Nutrients Removed Table 2012.xls) is used to calculate the value of nutrients exported in various crops. The P and K concentrations must be converted to the oxide form by multiplication of 2.29 * P = P_2O_5 and 1.2 *K = K_2O. Yield is multiplied by the nutrient concentration of each crop to determine nutrients removed in the crop.

Cost of Replacement of Nutrients Exported in Crops

This step calculates the cost of replacing nutrients exported in crops by applying nutrients as commercial fertilizers. Average fertilizer prices for southern Idaho are summarized by Patterson and Painter (2011) and shown in Table 3. Fertilizer prices should be compared on the basis of cost per pound of nutrient, not on the cost per pound of fertilizer material. I calculated the price of fertilizer on a multiple nutrient basis to fairly compare fertilizers (Table 4). The following process compares mixed blends of fertilizer sources:

1. First calculate the pounds of nutrients in a ton of fertilizer. To do this, add the percentage of nutrients together and multiply a ton by the sum.
   (2,000 lb. per ton x total percent nutrients = pound of nutrients in a ton of fertilizer.)

   Example 1: Urea (46-0-0-0)
   2,000 lb./ton x (0.46 + 0+ 0+0) = 920 lb. of nutrients in a ton of Urea.

   Example 2: Mono-ammonium phosphate, MAP (11-52-0-0)
   2,000 lb./ton x (0.11 + 0.52 + 0 + 0) = 1,260 lb. of nutrients in a ton of 11-52-0-0.

   There is quite a difference in the amount of nutrients you receive per ton of fertilizer. What does this mean economically?

2. I calculated fertilizer nutrient prices on the “Fert Price Multiple” sheet with data from Patterson and Painter 2011: Idaho Crop Input Price Summary for 2011. The cost per pound of nutrients in each fertilizer is calculated by dividing the cost per ton of fertilizer by the pounds of nutrients per ton.
   (Cost per ton ÷ pounds of nutrient per ton = cost per pound of nutrient.)

   Example 1: Urea (46-0-0-0)
   $555 per ton ÷ 920 lb. of nutrient per ton = $0.60 per lb. of nutrient.

   Example 2: Mono-ammonium phosphate (11-52-0-0)

   $725 per ton ÷ 1,260 lb. of nutrient/ton = $0.58 per lb. of nutrient for N and P_2O_5.

   In this example, 11-52-0-0 would be the better value if you need both N and P_2O_5. This method works as a basic comparison of multiple nutrient fertilizers, but does not take into account any difference in price between the different nutrients, as all nutrients have an equal value. This method can also be used to compare single nutrient fertilizers.
3. I used the price of N from urea and P_2O_5 from MAP for fertilizer products that are currently available in Idaho. The crop nutrient utilization data from IMC was also used as a comparison.

4. The lowest price of each nutrient (dollars/lb nutrient) is multiplied by the pounds of nutrient removed in the crop, which produces the value of nutrients in dollars/acre.

RESULTS

Amount of Nutrients Removed in Crops Each Year

The concentrations of nutrients in crops generally decline with plant maturity—especially forages where the whole plant 3 inches or more above the soil is harvested. For example, Figure 1 shows the nutrient concentrations of alfalfa forage as a function of growth stage. Soil type, fertility management, irrigation management, and harvest management also affect the nutrient composition of forages. Some nutrients are mobilized as grass crops senesce resulting in low concentrations in the straw, e.g. barley and wheat straw. We have focused on the mature stages of forages because yield and crop removal are maximized.

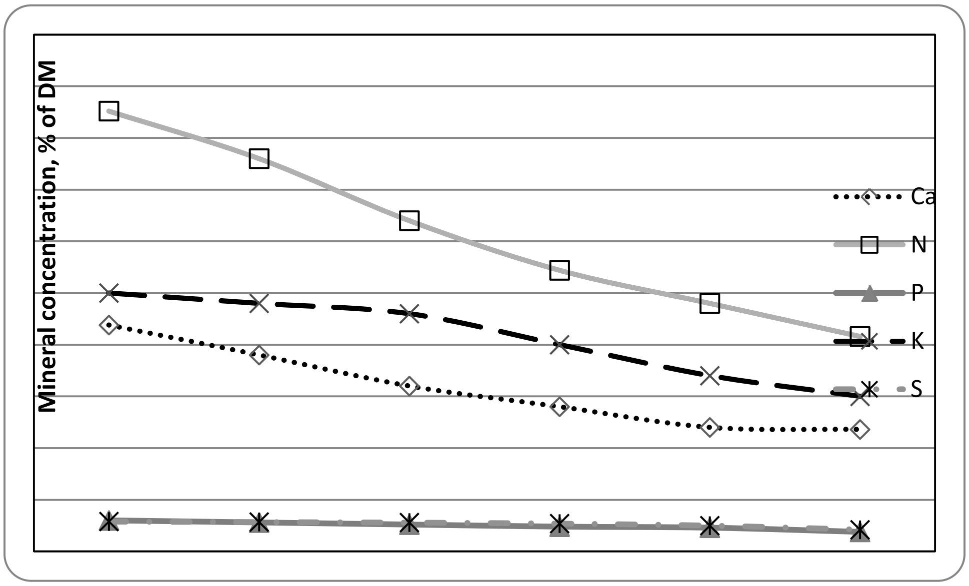

Figure 1. Mineral concentrations of alfalfa on a dry matter (DM) basis as a function of plant maturity or growth stage when harvested.

Yield is the largest variable in mineral removal that we can manage. The higher the yield, the higher the amount of nutrients removed. Alfalfa removes the most nutrients (913 lbs/acre) followed by corn silage at 809 lbs/acre, then barley silage at 295 lbs/acre (Table 2). The grain crops remove smaller amounts of nutrients (193 to 314 lbs/acre) but still important amounts in the long term.

The largest amount of N is removed in alfalfa. However, since alfalfa is a legume it uses the *Rhizobia* bacteria in the nodules to fix atmospheric N into the plant, and can leave up to 200 lbs N which can be mineralized and available to crops in the year following rotation out of alfalfa, even with the forage removed. This is called a N credit and considering this credit is a good nutrient management practice, especially in organic operations. Although alfalfa at bud stage removes 456 lbs N/acre and at full bloom 384 lbs N/acre, we can assume that N concentrations in the soil are not negatively affected. Peas and beans are also legumes which fix N, but less is available for a N credit in the year after production. Corn silage removes the second most N at 282 lbs/acre, and those pounds need replacement.

Phosphate removal is mostly a function of yield at sufficient or higher soil levels of P, since plant maturity doesn't affect the concentration much. There are some differences between crops. The largest amount of P_2O_5 removed is in corn silage, 116 lbs/acre at 11 tons DM yield or about 32 tons fresh silage/acre. Alfalfa at bud stage removes 84 lbs P_2O_5/acre at 8 tons/acre.

Potassium (K_2O) is the largest amount of nutrient removed with 456 lbs K_2O/acre in barley silage, 346 lbs K_2O/acre for alfalfa, and 385 lbs K_2O/acre for corn silage. Although most of our Idaho soils have had adequate soil levels of K_2O historically, 100 years of crop removal have mined the soils and we are seeing more soil test levels below 200 ppm K_2O (or 166 ppm K). Corn, alfalfa and other crops can take up more K than necessary for plant growth. This is called luxury consumption and will export more K if soil levels are high, often from high rates of manure application. Animal nutritionists do not want high K concentrations in forages because an improper ratio of K /(Ca + Mg) causes problems with milk fever and grass tetany.

Value of Nutrients Removed Each Year in Crops

Table 5 shows the value of nutrients removed each year in crops. Since the N removed in alfalfa is not a negative in the soil, we will deduct the N value from the total, resulting in $228 value of nutrients removed in alfalfa. Corn silage removes nutrients valued at $438/acre, followed by barley silage at $424/acre. Barley grain and straw combined removes nutrients valued at $313/acre. Corn grain removes nutrients valued at $163/acre. Grass hay removes much N and K which results in nutrients removed at $231/acre.

RECOMMENDATIONS

The removal of nutrients by crops, especially forage crops, should cause producers to consider the long term mining of nutrients from the soil. How sustainable is your nutrient management? In 100 years corn silage could remove over 22 tons of nutrients per acre from your soil. It should also be considered when marketing forage crops. With current fertilizer prices, how long can you afford to sell hay and corn silage and not get some of the nutrients back from the dairy or feedlot? It may be unreasonable in the short term to market forage crops based totally on nutrient removal because you would need to sell alfalfa hay at $38/ton and grass hay at $58/ton just to replace the N, P, K, and S (Table 5). Corn silage would require $40/ton DM or about $11/ton fresh corn silage to recover nutrient costs.

I recommend negotiating with your forage crop consumer to get back some of the nutrients in the form of manure, if you are close to the consumer, or compost if you are further away. That is simply good nutrient management and benefits both parties.

Table 1. Feed Mineral Table: Selected feedstuffs and nutrient concentration on a dry matter basis.

Feedstuff	DM	CP	Ash	Ca	N	P	K	S
	%	%	%	%	%	%	%	%
Alfalfa, bud stage	90	21	7	1.90	3.80	0.28	2.4	0.29
Alfalfa hay full bloom	88	16	8	1.20	2.40	0.23	1.7	0.25
Barley hay	90	9	8	0.30	1.44	0.28	1.6	0.19
Barley silage	35	12	9	0.46	1.92	0.30	2.4	0.22
Barley straw	90	4	7	0.33	0.64	0.08	2.1	0.16
Barley grain	89	13	3	0.06	1.92	0.38	0.6	0.16
Corn fodder	80	9	7	0.50	1.44	0.25	0.9	0.14
Corn stover mature	80	5	7	0.35	0.80	0.19	1.1	0.14
Corn silage mature	34	8	5	0.28	1.28	0.23	1.1	0.12
Corn grain whole	88	9	2	0.02	1.44	0.30	0.4	0.13
Grass hay	88	10	6	0.60	1.60	0.21	2.0	0.20
Meadow hay	90	7	9	0.61	1.12	0.18	1.6	0.17
Oat hay	90	10	8	0.40	1.60	0.27	1.6	0.21
Oat straw	91	4	8	0.24	0.64	0.07	2.4	0.22
Oat grain	89	13	4	0.05	2.08	0.41	0.5	0.20
Pea straw	89	7	7	0.60	1.12	0.15	1.1	0.15
Peas cull	89	25	4	0.15	4.00	0.45	1.1	0.26
Potatoes cull	21	10	5	0.03	1.60	0.24	2.2	0.09
Sorghum stover	87	5	10	0.49	0.80	0.12	1.2	
Sorghum silage	32	9	6	0.48	1.44	0.21	1.7	0.11
Sudangrass hay	88	9	10	0.50	1.44	0.22	2.2	0.12
Timothy hay full bloom	88	8	5	0.43	1.28	0.20	1.8	0.13
Triticale hay	90	10	8	0.30	1.60	0.26	2.3	
Triticale silage	34	14	7	0.58	2.24	0.34	2.7	0.28
Wheat straw	91	3	8	0.16	0.48	0.05	1.3	0.17
Wheat grain	89	14	2	0.05	2.24	0.43	0.4	0.15
Wheatgrass crested hay	92	10	7	0.33	1.60	0.20	2	

Table 2. Nutrient concentrations and mass of nutrients removed in selected crops.

Field Crops		Nutrient concentration				Nutrients removed in crop				
	Yield	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S	Sum
	ton/ac	lb/ton dry matter basis				- - - - - - lb/acre - - - - - -				
Barley grain	3.1	38.4	17.4	19	3.2	120	54	59	10	243
Corn grain	5.0	28.8	13.7	13	2.6	145	69	66	13	293
Oat Grain	2.4	41.6	18.8	16	4.0	100	45	38	10	193
Wheat Grain	3.9	44.8	19.7	13	3.0	175	77	51	12	314
Forage Crops										
Alfalfa hay at bud *	6	76	13	58	5.7	456	77	346	34	913
Alfalfa hay full bloom	8	48	11	41	5.0	384	84	326	40	835
Barley hay	6	29	13	51	3.8	173	77	306	23	578
Barley silage	6	38	14	76	4.4	230	82	456	26	795
Barley straw	4	13	4	66	3.2	51	15	264	13	343
Corn stover mature	7	16	9	35	2.8	112	61	245	20	438
Corn silage mature	11	26	11	35	2.4	282	116	385	26	809
Grass hay	4	32	10	63	4.0	128	38	252	16	434
Meadow hay	5	22	8	51	3.4	112	41	255	17	425
Oat hay	5	32	12	51	4.2	160	62	255	21	498
Oat straw	4	13	3	76	4.4	51	13	304	18	386
Pea straw	1	22	7	35	3.0	22	7	35	3	67
Timothy hay full bloom	4	26	9	57	2.6	102	37	228	10	378
Triticale hay	3	32	12	73	3.0	96	36	219	9	360
Triticale silage	2	45	16	85	5.6	90	31	170	11	302
Wheat straw	2	10	2	41	3.4	19	5	82	7	113

* Legumes obtain most of their N from the air.

Table 3. Current and historical fertilizer component prices for southern Idaho: 2009 – 2011 and percentage change from 2010 to 2011 (Patterson, 2011).

Source	Nutrient concentration	2009	2010	2011	Change
	(N-P_2O_5-K_20 %)				
Dry nitrogen	(46-0-0)	$0.50	$0.47	$0.61	30%
Liquid nitrogen	(32-0-0)	$0.56	$0.48	$0.70	46%
P_2O_5 dry	(11-52-0)*	$0.46	$0.34	$0.57	68%
P_2O_5 liquid	(10-34-0)*	$0.63	$0.50	$0.76	52%
K_2O	(0-0-60)	$0.69	$0.43	$0.51	19%
Sulfur		$0.19	$0.17	$0.22	29%

*Nitrogen in 11-52-0 and 10-34-0 was valued at the price of N in urea and Solution 32, respectively

Table 4. The value of fertilizer nutrients as commercial fertilizer.

Product	Fertilizer cost		Nutrient concentration				Total nutrients	Nutrient cost[1]			
			N	P_2O_5	K_2O	S		N	P_2O_5	K_2O	S
Nitrogen:	$/ton	$/lb	%	%	%	%	lb/ton	$/lb	$/lb	$/lb	$/lb
Ammonium sulfate	$410	$0.21	20	0	0	24	880	$0.47	--	--	$0.47
Urea	$555	$0.28	46	0	0	0	920	$0.60	--	--	--
Anhydrous ammonia	$945	$0.47	82	0	0	0	1640	$0.58	--	--	--
Solution 32 liquid	$445	$0.22	32	0	0	0	640	$0.70	--	--	--
Thio Sul liquid	$345	$0.17	12	0	0	26	760	$0.45	--	--	$0.45
Phosphate:											
16-20-0	$550	$0.28	16	20	20	0	1120	$0.49	$0.49	$0.49	--
11-52-0 (MAP)	$725	$0.36	11	52	0	0	1260	$0.58	$0.58	--	--
10-34-0 (liquid)	$657	$0.33	10	34	0	0	880	$0.75	$0.75	--	--
3-30-0-4	$575	$0.29	3	30	0	4	740	$0.78	$0.78	--	$0.78
11-37-0	$600	$0.30	11	37	0	0	960	$0.63	$0.63	--	--
Potash:											
Muriate of potash	$615	$0.31	0	0	60	0	1200	--	--	$0.51	--
Sulfate of potash	$680	$0.34	0	0	50	17	1340	--	--	$0.51	$0.51
Liquid potash	$180	$0.09	0	0	13	0	260	--	--	$0.69	--
Sulfur:											
Elemental (90%)	$390	$0.20	0	0	0	90	1800	--	--	--	$0.22

Table 5. The value of nutrients removed in selected crops. Nutrient values used were: N at \$0.60/lb, P_2O_5 at \$0.58/lb, K_2O at \$0.51/lb, and S at \$0.22/lb.

Field Crops	**Yield**	**Value of nutrients exported**					
		N	**P_2O_5**	**K_2O**	**S**	**Total**	
	ton/ac	Dollars/acre					\$/ton
Barley grain	3.1	72	31	30	2	136	\$ 44
Corn grain	5.0	87	40	33	3	163	\$ 32
Oat Grain	2.4	60	26	20	2	108	\$ 45
Wheat Grain	3.9	105	45	26	3	178	\$ 46
Forage Crops							
Alfalfa hay at bud *	6	274	45	176	8	228	\$ 38
Alfalfa hay full bloom	8	230	49	166	9	224	\$ 28
Barley hay	6	104	45	156	5	309	\$ 52
Barley silage	6	138	48	233	6	424	\$ 71
Barley straw	4	31	9	135	3	177	\$ 44
Corn stover mature	7	67	35	125	4	232	\$ 33
Corn silage mature	11	169	67	196	6	438	\$ 40
Grass hay	4	77	22	129	4	231	\$ 58
Meadow hay	5	67	24	130	4	225	\$ 45
Oat hay	5	96	36	130	5	267	\$ 53
Oat straw	4	31	7	155	4	197	\$ 49
Pea straw	1	13	4	18	1	36	\$ 36
Timothy hay full bloom	4	61	21	116	2	201	\$ 50
Triticale hay	3	58	21	112	2	192	\$ 64
Triticale silage	2	54	18	87	2	161	\$ 81
Wheat straw	2	12	3	42	1	58	\$ 29
* Legumes obtain most of their N from the air.							

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