DEVELOPMENT OF THE GRASSGRO MODEL IN SUPPORT OF A DROUGHT MANAGEMENT STRATEGY FOR LIVESTOCK ENTERPRISES

Final Report

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Table of Contents

List of Tables and Figures

Tables

Figures

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Abstract

This project arose from a perceived need for weather based crop insurance adjustments. GrassGro is a computer simulation model that predicts the growth and production of a wide range of pasture forage species from weather data. It can also predict the forage intake and production of various classes of grazing livestock. The objective of this project was to provide the Saskatchewan Crop Insurance Corporation with a computerized method of assessing the production of forage crops from weather data collected at various locations throughout the province of Saskatchewan.

This report provides information on the production of three pasture associations predicted from weather records collected at 81 locations in Saskatchewan or border towns in neighbouring provinces. The three pasture associations were alfalfa/grass, crested wheatgrass and mixed grass native range. Maximum forage production was simulated at each location using daily weather records from January 1, 1960 to December 31, 2000. Data for each year and the 41-year average were tabulated. Examples were provided to suggest how these data could be used for insurance adjustment purposes.

The complete data set and a working copy of the GrassGro software will be provided to the Saskatchewan Crop Insurance Corporation on compact disk. For the purpose of brevity, this report only presents examples from 5 locations Butte St Pierre, Hudson Bay, Val Marie, Estevan and Last Mountain Lake. The report also provides some discussion of the data and indicates that weather based predictions should consider more than just rainfall during the pasture growing season of a single year.

Introduction

The GrassGro Decision Support Tool (DST) is a weather based computer model that will predict the growth of pastures that may contain any number of different species of grasses (native, seeded, annual or perennial) and legumes. The pasture may be situated on any of 13 different top-soil and 13 different sub-soil types based on texture. The fertility of the soil is defined on a scale of 0 to 1, representing a sterile medium (0) to a medium where plant nutrients have been maximized with applications of appropriate fertilizers (1). Above and below ground biomass in the changing pools of plant roots, green and dead herbage and litter is estimated. Changing pasture quality is estimated as digestibility and protein content of the various pools.

The pasture may be ungrazed, cut for hay or grazed by single or mixed classes of cattle (cows, calves, steers or heifers) or sheep (ewes, lambs or wethers). Hay may be cut to a user-defined height above the soil surface on a user-entered date or yield and any number of cuts may be taken each year. If the pasture is grazed, it can be grazed at any user-defined stocking rate for any period of time as a single continuously grazed pasture, or it may be cross-fenced and grazed in a rotation or complementary system. If the pasture is grazed, herbage selection from the various plant pools and the amount of herbage eaten by the various classes of livestock is estimated. The digestibility and protein content of the consumed herbage is estimated and the resulting energy and protein consumption is used to estimate nutrient assimilation as liveweight, milk production, body condition score and reproductive rate.

Daily meteorological data are required as inputs that drive the model. These are precipitation, maximum and minimum temperature, evaporation and solar radiation. If evaporation is not available GrassGro can calculate it from temperature and wind data. If solar radiation is not available it can be calculated from sunshine hours or from the coordinates of latitude and longitude of the location. Missing data are entered using one or a combination of several methods. These include: long-term mean for the element for the missing day(s); data for the element from the previous or next day; data for the element from the nearest recording station(s).

GrassGro requires a continuum of weather data from January 1 to December 31 for each year. This is because the amount of precipitation (rain and snow) during pasture dormancy adds moisture to the soil for the next growing period, evaporation during dormancy reduces soil moisture and temperature and moisture will influence non-seasonal re-growth and plant survival during winter. GrassGro also provides a calculation of gross margin (GM) returns and risk based on user-entered costs and prices and the standard deviation of the GM.

Objective

The objective of this project was to provide the Saskatchewan Crop Insurance Corporation with a weather-based model and long-term historic weather data for evaluation as a tool for drought management strategy for livestock enterprises.

Methods

Daily simulations were compiled for each of the 81 locations from 1 January 1960 to 31 December 2000 with the exception of border locations in Alberta and Manitoba. For those locations, simulations were compiled from 1 January 1960 to 31 December 1998. In addition, daily data for Harris and Shackleton were available only for 1 January 1960 to 31 December 1998 and for Spiritwood from 1 January 1960 to 31 December 1999.

Pastures

Three pasture associations were simulated at each location. These were:

1. Alfalfa/meadow bromegrass/Russian wild ryegrass
2. Crested wheatgrass
3. Native pasture (northern wheatgrass, western wheatgrass, green needle grass, blue grama grass and June grass).

Site considerations

Site considerations were the same for all locations. This was considered desirable to reduce the complexity and to ensure that production differences between locations was based only on differences in weather. The site considerations were:

1. Soil – sandy loam top-soil and loam sub-soil
2. Slope – level
3. Fertility scalar – 0.8.

Management

All locations were simulated as ungrazed pastures. This was considered necessary to remove differences between locations based on management factors such as dates on and off pasture, stocking rates etc. However, ungrazed pasture is unrealistic and if the current year's growth is not removed it will negatively influence growth in the following year. Therefore in all simulations the standing pasture was cut 20mm above ground level and removed (hay simulation) on September 30 each year at the end of the growing season.

Presentation of results

The complete set of results is very extensive. Therefore, this report presents only some examples from 5 locations. The complete set of results and all GrassGro files will be supplied to the Saskatchewan Crop Insurance Corporation on the acceptance of this report. Readers who require results for locations not included here should direct their requests to the Saskatchewan Crop Insurance Corporation. All results are presented in metric units. However, these can be readily converted to non-metric units in the Excel spreadsheets that can be found on the CD supplied the Saskatchewan Crop Insurance Corporation. All graphic presentations are in the GrassGro output format and have not been re-drawn.

A. Production considerations

GrassGro provides a wide range of information but the information considered relevant for crop insurance was:

1. Annual and long-term average (1961-2000) total precipitation
2. Annual and long-term average (1961-2000) maximum production of pasture expressed as green herbage, dead herbage + litter and total herbage.

Although simulations were run from January 1, 1960, results are presented only for the years 1961-2000. This is because at the start of simulations on January 1, 1960 the same soil moisture content and available forage was entered for each location. This is unrealistic so the first year's simulated data (1960) are not reported but were used as the starting point for soil moisture and available forage on January 1, 1961. Precipitation and total herbage production are considered to be the most important parameters for insurance adjustments. Daily maximum and minimum temperatures are also important in determining plant growth dynamics but these are not presented in this written report. This is because temperature affects plants on a daily basis and cannot be summarized in a meaningful way as total or average temperature because it cannot be stored for future use in the way that precipitation can be stored as moisture in the soil. Temperature information, if required, can be obtained on request from the Saskatchewan Crop Insurance Corporation.

It is important to note that the various plant pools that contribute to the total herbage biomass are changing on a daily basis: green herbage senesces and dies; dead herbage becomes litter and decays; new green herbage grows and so on depending on management inputs and environmental conditions. Thus the maximum biomass in each pool does not occur on the same day. GrassGro predicts phenological development very accurately. For example death of a grass leaf is not all or nothing. Senescence takes place progressively along the leaf blade so if 10% of the leaf has senesced, that 10% moves from the green to the dead herbage pool and so on whereas a visual estimate would place the whole leaf in the green pool until most of the leaf was dead. However, it is the total biomass pool that is cut for hay or from which the animal selects its diet.

The effect of management on plant pool dynamics is also important. For example, defoliation (cutting or grazing) and in particular, the timing and extent of the defoliation will affect the amount of green and dead herbage removed and affect the amount of re-growth of green herbage and hence the total herbage pool. Fertilizer, stocking rate, class and breed of cattle and so on will also affect plant pool dynamics. Soil texture will also affect the plant pool dynamics because of its effects on moisture holding capacity. GrassGro can accommodate individual farm management inputs but this is not realistic from a crop insurance perspective because each pasture area between and within farms would require a separate simulation. It was therefore considered important to remove management and soil texture as influencing factors by setting these constant throughout and base comparisons between locations on climatic conditions alone.

The data presented in this report therefore do not represent management inputs. No farmer would leave a pasture ungrazed and then cut it for hay at the end of September. For that reason, neither do the data represent absolute hay or grazed pasture yields but they do represent forage production comparisons between and within locations that are due entirely to prevailing climatic conditions.

B. Financial considerations

It is not the purpose of this report to advise the Saskatchewan Insurance Corporation how to calculate their insurance adjustments. However, it does seem appropriate to provide an example of adjustment calculations based on the data provided in this report.

For example, let us assume that a particular type of pasture is valued $44/tonne ($40/ton) and let us assume that the long-term average maximum production is 1956kg/ha (1745lb/ac) at a particular location. Now assume that the insured pasture is 65ha ($^1/_4$ section) in area and in the adjustment year the production is 436 kg/ha (389lb/ac) based on GrassGro simulations using weather data for that year (1kg/ha = 0.892lb/ac). The theoretical calculation is as follows:

Long-term average production 1961-2000	= 1956kg/ha	(1745lb/ac)
Value of average long-term production (1.956t x $44)	= $86/ha	($34.80/ac)
Production for adjustment year is (436/1956) x 100%	= 22.3%	(0.223)
Adjustment payment @ $86 x (1 – 0.223)	= $66.82/ha	($27.12/ac)
Adjustment payment for 65ha (160 ac)	= $4,343	($4,339)

The difference between calculations in hectares and acres is due to rounding of conversions.

Alternatively, SCIC may allow the farmer to choose coverage up to but not exceeding the long-term average value ($34.80/ac). If the farmer chooses coverage at $20/ac for example, the adjustment in the above example would be 77.7% of $20 = $15.54/ac or $2,486 for 160ac.

C. Risk considerations

GrassGro provides cumulative and probability distribution functions. These can be applied to the long-term total precipitation data or to the long-term average total herbage production to estimate insurance risk. For example, in the above example, the probability of the location getting the precipitation that resulted in the reduced pasture production may be greater or less than that at a near-by location and this could be taken into consideration with respect to premium determination. Examples will be presented in the next section.

Simulation results

GrassGro presents the results of simulations in either graphic or tabular format. Either format can be copied and pasted into Microsoft word, PowerPoint and Excel documents and edited as required. Tabulated results for precipitation and pasture production for each year at each location can be found in the file <Maximum Forage 1961-2000.XLS> in the folder <Sask Crop Insurance> on the CD provided to the Saskatchewan Crop Insurance Corporation (SCIC). All results in either tabular or graphic format can be accessed from the CD by opening a file <*location*.GRW> within GrassGro (open <GrassGro.EXE>) where *location* can be any of the 81 locations listed in Appendix 1. Any of the simulation results can then be viewed by selecting the required result and its presentation format from the dialogue boxes on the screen. Readers requiring information from a location not presented in this report should request it from SCIC.

The 5 locations chosen for presentation in this report represent locations in the north west, north east, south west, south east and central regions of Saskatchewan's agricultural belt. The locations are: Pierre St. Butte, Hudson Bay, Val Marie, Estevan and Last Mountain lake.

Precipitation and forage production

Annual and long term average total precipitation and forage production for the 5 example locations is shown in Tables 1-5.

Table 1. Annual precipitation and maximum forage production at Butte St. Pierre 1961-2000.

		Alfalfa / Grass			Crested wheat			Native Pasture		
	Ppt (mm)	Green	Dead+Litter	Total	Green	Dead+Litter	Total	Green	Dead+Litter	Total
	Jan-Dec	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
1961	325	1657	3759	5416	1607	2761	4368	950	2186	3136
1962	455	4329	7828	12157	2885	3569	6454	1002	1248	2249
1963	382	3498	5736	9234	3248	4125	7372	1039	1682	2721
1964	460	1965	2492	4457	1416	1637	3053	804	1461	2265
1965	473	4251	4925	9176	5976	6540	12516	1012	2639	3651
1966	345	3970	5147	9116	3563	4643	8206	1275	1400	2675
1967	365	2853	3807	6661	4213	4988	9201	1195	1895	3090
1968	415	2497	3157	5654	2971	3818	6789	1169	1787	2955
1969	392	1689	2476	4165	3153	4635	7788	1009	2473	3482
1970	506	3846	4835	8681	4631	5390	10021	1461	2019	3480
1971	431	3827	5509	9336	4874	6066	10939	1742	2680	4423
1972	407	2924	4362	7285	3368	4487	7855	1522	3335	4857
1973	482	2984	4310	7293	3498	4359	7856	1476	2200	3676
1974	398	3205	4498	7704	4790	5770	10560	1260	2459	3719
1975	468	1162	1717	2879	2237	2909	5146	959	1673	2631
1976	356	1652	2714	4366	1960	2544	4504	906	1809	2716
1977	489	2247	3234	5480	2325	2933	5257	1293	1787	3079
1978	444	2107	3319	5426	2952	3356	6308	1141	1949	3090
1979	408	1496	2107	3602	3172	4436	7608	882	2001	2882
1980	412	2068	3249	5317	2662	2880	5542	1360	2252	3612
1981	324	1736	2624	4360	2188	2915	5103	817	1935	2753
1982	401	609	1072	1681	1490	2062	3552	516	1147	1663
1983	421	1191	1970	3161	1723	2193	3915	562	1376	1938
1984	500	2473	3327	5800	3656	4501	8157	714	1776	2490
1985	361	1429	2688	4117	2437	3334	5771	749	2105	2854
1986	511	3242	3410	6652	4301	4666	8967	1228	1217	2444
1987	421	3549	3622	7171	2862	3106	5968	1518	2113	3631
1988	519	2875	4141	7016	3434	3578	7012	1775	2765	4539
1989	365	2244	3362	5606	2990	4797	7788	1038	3109	4147
1990	326	1602	2402	4005	2268	2936	5204	939	1704	2643
1991	339	873	1865	2738	1639	2434	4072	569	1467	2036
1992	333	457	1358	1815	897	1356	2253	224	1326	1550
1993	300	88	702	790	470	782	1252	63	736	800
1994	385	979	1502	2482	1427	1726	3153	201	563	765
1995	300	335	1080	1415	434	967	1400	56	707	763
1996	415	1013	1207	2219	1667	1916	3583	293	740	1033
1997	429	1639	2760	4400	2123	2953	5076	427	1201	1629
1998	323	681	1524	2206	922	1549	2471	346	1297	1643
1999	419	1991	3081	5072	2041	2424	4465	479	1310	1789
2000	403	3053	3715	6768	2431	2747	5178	635	1351	1985
Average	405	2157	3165	5322	2672	3370	6042	915	1772	2687

Table 2. Annual precipitation and maximum forage production at Hudson Bay 1961-2000.

	Ppt (mm)	Alfalfa / Grass			Crested wheat			Native Pasture		
	Jan-Dec	Green kg/ha	Dead+Litter kg/ha	Total kg/ha	Green kg/ha	Dead+Litter kg/ha	Total kg/ha	Green kg/ha	Dead+Litter kg/ha	Total kg/ha
1961	312	1233	3638	4871	1330	2391	3722	799	2803	3602
1962	435	2692	3371	6064	3247	3567	6814	860	1673	2533
1963	467	2671	4532	7202	3403	4148	7551	910	1508	2418
1964	500	3798	2136	5934	3726	3589	7316	1035	2620	3655
1965	596	4062	2608	6670	7689	8022	15711	1093	2323	3416
1966	526	3481	3423	6904	5300	6831	12131	1521	1440	2961
1967	367	1794	2852	4646	3108	4725	7833	1143	2430	3573
1968	497	5111	5518	10629	5576	5297	10872	1379	1614	2993
1969	410	1644	2318	3961	3670	4942	8612	1051	2573	3624
1970	577	4535	5639	10174	5548	6306	11855	1379	1881	3260
1971	479	3382	4958	8340	4646	6138	10784	1467	2555	4022
1972	363	2490	4713	7203	4500	6268	10767	1379	3689	5068
1973	599	3507	4847	8354	5544	6069	11613	1534	2391	3926
1974	495	2488	1509	3996	4803	4783	9585	1303	2276	3579
1975	468	2887	2608	5495	5923	7409	13332	1560	1662	3222
1976	412	4205	6186	10391	4721	6094	10814	1494	3268	4762
1977	476	2622	2631	5253	2275	2588	4863	1474	1952	3426
1978	540	3100	3903	7002	4353	4502	8855	1409	2163	3571
1979	412	1895	2530	4425	4714	6231	10945	1161	2453	3614
1980	475	2569	3489	6058	3289	3338	6627	1517	2530	4047
1981	466	2431	3929	6360	3495	4847	8342	1211	2654	3866
1982	420	2077	1419	3496	4954	5804	10758	1171	1912	3083
1983	559	2850	2089	4939	5378	6208	11587	1545	2415	3960
1984	549	2721	3354	6075	5048	5996	11045	1008	2797	3806
1985	462	4019	5305	9324	5803	6742	12545	1303	2139	3441
1986	356	1485	3018	4503	2723	4327	7049	1085	1889	2974
1987	428	1845	2759	4604	2960	3483	6444	1134	1922	3056
1988	446	1727	2838	4565	2423	3261	5684	1261	2439	3699
1989	467	1783	2638	4421	2601	3238	5838	984	2463	3447
1990	393	2618	3699	6317	4206	5001	9207	1130	2002	3132
1991	438	1785	2683	4467	2679	3391	6070	1124	2338	3462
1992	386	1408	2419	3826	2339	2712	5051	795	1701	2496
1993	545	3811	3869	7679	5610	2403	8013	1056	1943	2998
1994	395	3115	4751	7865	4868	6647	11515	1180	1544	2724
1995	445	1158	1442	2600	3075	2750	5825	1127	2157	3285
1996	479	1478	1629	3106	3621	4648	8269	1272	1940	3211
1997	496	2603	3760	6363	3671	3902	7573	1530	1792	3322
1998	454	3003	4217	7220	4236	5295	9531	1454	2861	4315
1999	477	2995	4427	7422	4210	5209	9419	1284	2694	3978
2000	484	3491	4816	8306	5142	5889	11031	1213	1976	3189
Average	464	2714	3462	6176	4160	4875	9035	1233	2234	3468

Table 3. Annual precipitation and maximum forage production at Val Marie 1961-2000.

		Alfalfa / Grass			Crested wheat			Native Pasture		
	Ppt (mm) Jan-Dec	Green kg/ha	Dead+Litter kg/ha	Total kg/ha	Green kg/ha	Dead+Litter kg/ha	Total kg/ha	Green kg/ha	Dead+Litter kg/ha	Total kg/ha
1961	213	262	1447	1709	330	745	1076	330	851	1182
1962	447	1706	3502	5208	884	1091	1975	264	841	1106
1963	248	1142	3512	4654	1101	1910	3012	145	928	1073
1964	336	902	2753	3655	902	1179	2081	367	942	1309
1965	449	1976	3551	5528	2040	2301	4342	570	1615	2184
1966	305	516	1618	2134	809	1219	2028	263	1256	1519
1967	296	574	1498	2072	485	786	1272	117	584	700
1968	220	39	438	477	246	583	829	11	618	630
1969	381	1260	1792	3052	1618	1841	3459	167	535	702
1970	326	1050	1846	2895	1215	1746	2961	249	1161	1410
1971	262	1444	2397	3840	1841	2241	4082	346	989	1335
1972	311	924	2158	3082	1421	2086	3507	467	1399	1866
1973	271	150	906	1057	597	1082	1679	131	925	1057
1974	381	1292	2601	3893	2060	2194	4254	351	866	1217
1975	471	2107	3577	5684	2971	3351	6322	553	1340	1892
1976	280	1959	3443	5402	2400	3196	5596	616	1692	2308
1977	294	505	1418	1923	731	1201	1932	290	767	1057
1978	387	2267	3833	6100	1936	2313	4249	404	959	1363
1979	296	1577	3657	5233	2115	2920	5035	439	1355	1794
1980	291	254	1054	1308	861	1408	2269	291	1378	1669
1981	264	98	732	829	491	880	1371	53	601	654
1982	362	1458	2879	4337	1801	2133	3934	122	462	584
1983	249	625	1467	2092	1107	1880	2987	182	987	1169
1984	203	81	436	517	279	577	856	18	761	779
1985	297	65	407	472	267	503	770	7	498	505
1986	441	725	1322	2047	1260	1548	2809	273	701	973
1987	264	1077	2551	3628	1925	2507	4432	588	1355	1943
1988	235	238	824	1062	326	671	998	351	857	1208
1989	404	47	499	546	280	523	803	107	571	678
1990	364	62	521	582	277	546	823	0	399	399
1991	480	1719	3235	4954	1626	2308	3934	307	756	1063
1992	336	858	2275	3133	794	1079	1873	218	1267	1485
1993	446	1667	3236	4903	911	1111	2022	333	751	1085
1994	312	696	1629	2325	1543	2109	3652	329	898	1227
1995	461	268	1190	1458	643	1123	1765	77	854	931
1996	323	118	788	906	586	953	1538	110	608	718
1997	351	1238	2374	3611	1986	2499	4484	395	890	1284
1998	360	494	1431	1925	847	1272	2119	340	1014	1354
1999	374	783	1693	2476	1597	2207	3804	393	1296	1689
2000	488	1513	2244	3757	1939	2370	4309	502	961	1463
Average	337	893	1968	2862	1176	1605	2781	277	937	1214

Table 4. Annual precipitation and maximum forage production at Estevan 1961-2000.

		Alfalfa / Grass			Crested wheat			Native Pasture		
	Ppt (mm) Jan-Dec	Green kg/ha	Dead+Litter kg/ha	Total kg/ha	Green kg/ha	Dead+Litter kg/ha	Total kg/ha	Green kg/ha	Dead+Litter kg/ha	Total kg/ha
1961	240	49	559	608	386	779	1165	302	825	1126
1962	430	1774	3873	5647	1568	1915	3483	400	914	1314
1963	575	2351	2916	5268	2951	3454	6405	838	1089	1927
1964	421	1729	2844	4574	2505	2953	5458	755	2305	3060
1965	472	2224	2913	5137	2680	3302	5982	673	1830	2503
1966	307	673	1629	2301	1189	2220	3408	384	1468	1852
1967	311	543	1161	1704	831	1196	2027	258	881	1139
1968	419	465	513	978	286	673	959	186	668	854
1969	483	3260	3972	7232	3960	4517	8477	635	863	1497
1970	557	3368	4677	8045	4345	5758	10103	1010	1751	2761
1971	428	2173	2996	5169	2966	3763	6729	1016	2123	3139
1972	446	2258	3113	5370	2846	3703	6548	980	2051	3031
1973	416	755	1600	2355	1258	2091	3350	508	1563	2071
1974	393	1705	2686	4391	2771	3389	6160	656	1314	1970
1975	634	2694	2816	5510	3608	4050	7658	1216	1429	2645
1976	358	3584	5632	9216	5663	6989	12652	1388	2982	4370
1977	337	766	1552	2319	1290	1547	2837	520	1071	1592
1978	531	2334	3348	5682	2468	2845	5312	655	1231	1886
1979	329	1376	3798	5175	2323	3351	5674	570	1715	2285
1980	406	515	1335	1850	586	1088	1674	484	1332	1816
1981	408	101	720	822	468	880	1348	156	869	1025
1982	443	1987	3668	5655	1716	2189	3905	363	677	1039
1983	352	747	1649	2396	1316	2142	3458	295	1371	1666
1984	386	108	633	741	480	892	1372	89	917	1006
1985	432	933	1422	2354	1084	1327	2411	359	787	1146
1986	462	1982	3079	5061	2857	3858	6715	702	1167	1869
1987	343	538	1527	2065	953	1755	2708	586	1777	2363
1988	368	222	687	909	416	812	1228	160	686	846
1989	339	558	1154	1712	892	1262	2155	195	733	927
1990	378	1011	1549	2560	1359	1775	3134	326	908	1233
1991	579	1356	2578	3933	1813	2604	4417	750	1389	2138
1992	310	620	1294	1914	1114	1631	2745	461	1175	1637
1993	505	1098	1587	2685	1163	1468	2631	474	1023	1498
1994	447	1912	2757	4669	2858	3659	6517	807	1275	2082
1995	506	885	2396	3281	1375	2154	3528	343	1715	2059
1996	446	1017	1845	2862	1684	2414	4098	363	1065	1428
1997	347	806	1651	2456	1266	1817	3083	503	1127	1629
1998	499	877	1764	2640	1391	2055	3446	564	1630	2193
1999	503	2817	3654	6471	4003	4724	8727	882	1766	2647
2000	564	1588	2675	4263	2417	3117	5533	855	1834	2688
Average	428	1394	2306	3699	1928	2553	4481	567	1332	1899

Table 5. Annual precipitation and maximum forage production at Last Mountain Lake 1961-2000.

		Alfalfa / Grass			Crested wheat			Native Pasture		
	Ppt (mm) Jan-Dec	Green kg/ha	Dead+Litter kg/ha	Total kg/ha	Green kg/ha	Dead+Litter kg/ha	Total kg/ha	Green kg/ha	Dead+Litter kg/ha	Total kg/ha
1961	231	73	1043	1115	696	1237	1933	290	897	1187
1962	435	2287	4040	6327	1967	2297	4265	506	930	1436
1963	429	2644	3898	6542	2762	3260	6022	583	1312	1895
1964	324	443	1296	1738	1057	1518	2575	393	1161	1554
1965	484	2977	4230	7207	3335	3779	7114	680	1695	2376
1966	403	3014	5736	8751	2988	3830	6818	967	1426	2392
1967	332	1823	4102	5924	2415	2868	5283	778	1408	2186
1968	348	2100	3735	5834	1408	1822	3231	953	1509	2462
1969	406	1083	2047	3129	1840	3003	4843	643	2033	2676
1970	389	2272	3433	5705	2834	3491	6325	672	1433	2105
1971	382	3439	4790	8229	3622	4259	7881	1127	1715	2842
1972	260	456	1532	1988	977	1960	2937	436	1384	1820
1973	476	1744	3891	5635	1605	2017	3622	408	919	1327
1974	453	2393	3706	6099	2022	1985	4007	825	1160	1985
1975	342	648	1644	2292	2002	2784	4786	609	1865	2474
1976	366	2478	3745	6223	3216	4016	7232	925	1692	2617
1977	345	1343	2573	3916	2040	2624	4664	756	1626	2382
1978	360	1285	2125	3409	1538	2222	3760	609	1463	2073
1979	237	186	1043	1229	460	891	1351	222	891	1113
1980	326	316	1082	1398	552	825	1377	226	834	1060
1981	447	1134	2063	3198	1218	1561	2779	355	854	1209
1982	340	2258	3662	5920	2920	3612	6532	520	1240	1760
1983	402	1794	3123	4917	2325	3010	5335	626	1933	2559
1984	279	173	824	997	661	1118	1778	174	1046	1220
1985	387	1314	2558	3872	2266	2718	4984	457	902	1358
1986	359	1257	2513	3770	1360	2151	3511	725	1120	1844
1987	336	837	1852	2689	735	1205	1940	412	1127	1539
1988	231	36	639	674	215	637	852	143	799	942
1989	352	296	851	1147	764	1076	1840	142	599	740
1990	243	1262	2362	3624	1682	2131	3812	291	782	1072
1991	584	3531	5230	8761	3593	4043	7636	883	1499	2383
1992	359	1174	2176	3350	2242	3365	5606	1015	2069	3084
1993	471	1133	2029	3162	1744	2084	3829	621	1310	1931
1994	388	1608	2843	4451	2527	3292	5819	932	1564	2497
1995	441	1325	3058	4383	1492	2531	4024	677	2307	2983
1996	318	871	2164	3034	1545	2447	3992	335	1528	1864
1997	273	639	1570	2208	1099	1515	2614	327	808	1135
1998	447	1475	2246	3721	2066	2624	4690	543	1281	1824
1999	322	1930	3039	4969	2530	3503	6034	683	1528	2212
2000	371	406	975	1381	756	1062	1817	198	646	844
Average	367	1436	2637	4073	1827	2409	4236	567	1307	1874

Adjustment calculations

Using the formula developed on Page 6, examples of adjustment calculations for ¼ section (65ha) of crested wheatgrass pasture valued at $40/ton at each of these 5 locations are as follow:

Butte St Pierre

Average value 1961-2000	= ($40 x 160 x 6042 x 0.892)/2000
	= $17,246.29
1984 adjustment rate @ 100-[100(8157/6042)]	= 135%
Adjustment	= No adjustment necessary

Hudson Bay

Average value 1961-2000	= ($40 x 160 x 9035 x 0.892)/2000
	= $25,789.50
1984 adjustment rate @100-[100(11045/9035)]	= 122.2%
Adjustment	= No adjustment necessary

Val Marie

Average value 1961-2000	= ($40 x 160 x 2781 x 0.892)/2000
	= $7,938.09
1984 adjustment rate @ 100-[100(856/2781)]	= 69.2%
Adjustment @ 0.692 x $7938.09	= $5,493.16

Estevan

Average value 1961-2000	= ($40 x 160 x 4481 x 0.892)/2000
	= $12,790.57
1984 adjustment rate @ 100-[100(1372/4481)]	= 69.4%
Adjustment @ 0.694 x $12790.57	= $8,876.66

Last Mountain Lake

Average value 1961-2000	= ($40 x 160 x 4236 x 0.892)/2000
	= $12,091.24
1984 adjustment rate @ 100-[100(1778/4236]	= 58.0%
Adjustment @ 0.58 x $12091.24	= $7,012.92

Probability functions for annual precipitation

Figure 1 provides a graphic comparison for annual precipitation at Butte St Pierre, Hudson Bay, Val Marie and Estevan 1960-2000. Annual precipitation (mm rainfall equivalents) is shown on the Y axis and each bar represents one year from 1960 to 2000 (X axis).

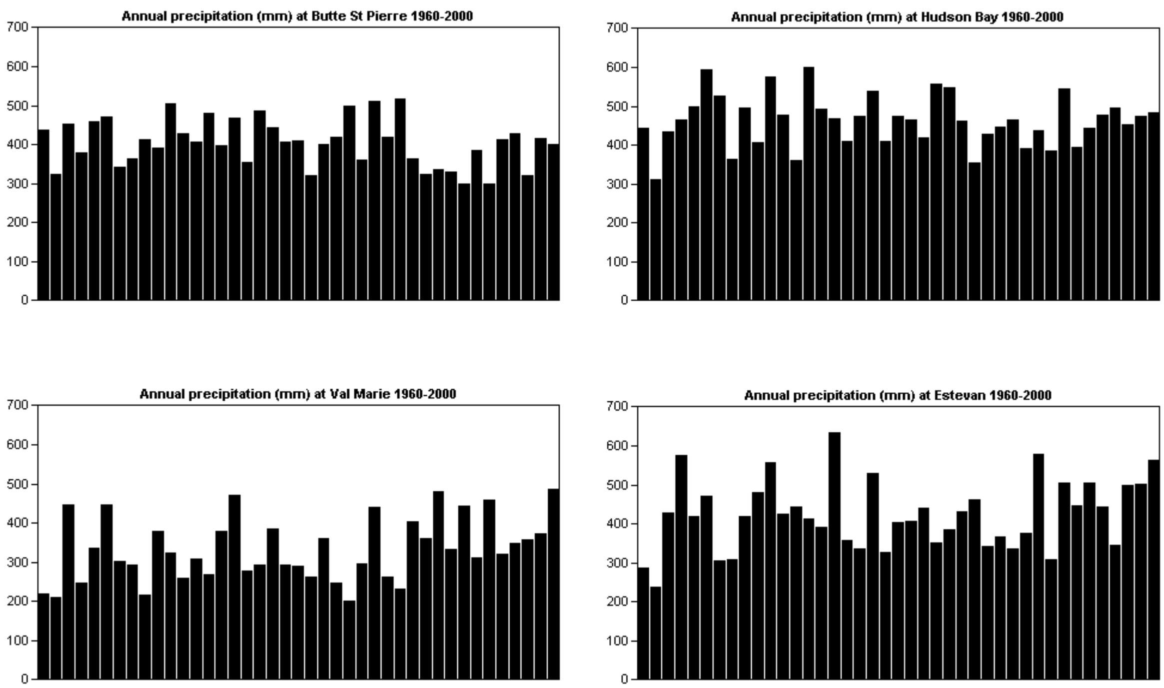

Figure 1. Annual precipitation (mm) at four locations in Saskatchewan 1960-2000.

The amount and variability of precipitation differs considerably at the four locations and between years at each location. This is illustrated in Figure 2 with a comparison of the probability distribution functions (PDF) for the 4 locations. The PDF provides a breakdown of the probability of receiving an annual precipitation within a range of amounts. The probability is shown on the Y axis as a range from 0 to 1 (0 to 100%) chance of receiving an annual amount or rain within the range shown on the X axis. It should be noted that graphs are shown as they are presented in GrassGro and that the X axis on all PDF graphs does not cover the same range. The range on the X axis is consistent with the data for each individual location and care should be exercised when comparing these graphs between locations. Comparisons between locations can be made more appropriately from the cumulative distribution functions (CDF) shown, for example, in Figure 3.

Thus, the range in precipitation varies from 290 to 540 mm at Butte St Pierre, 310 to 610mm at Hudson Bay, 200 to 500mm at Val Marie and 230 to 730mm at Estevan. The most probable precipitation at Butte St Pierre is 390 to 440mm (36.6% probability); at Hudson Bay it is 410 to 510mm (61% probability); at Val Marie it is 200-300mm (41.5% probability) and at Estevan it is 330 to 430mm (41.5% probability).

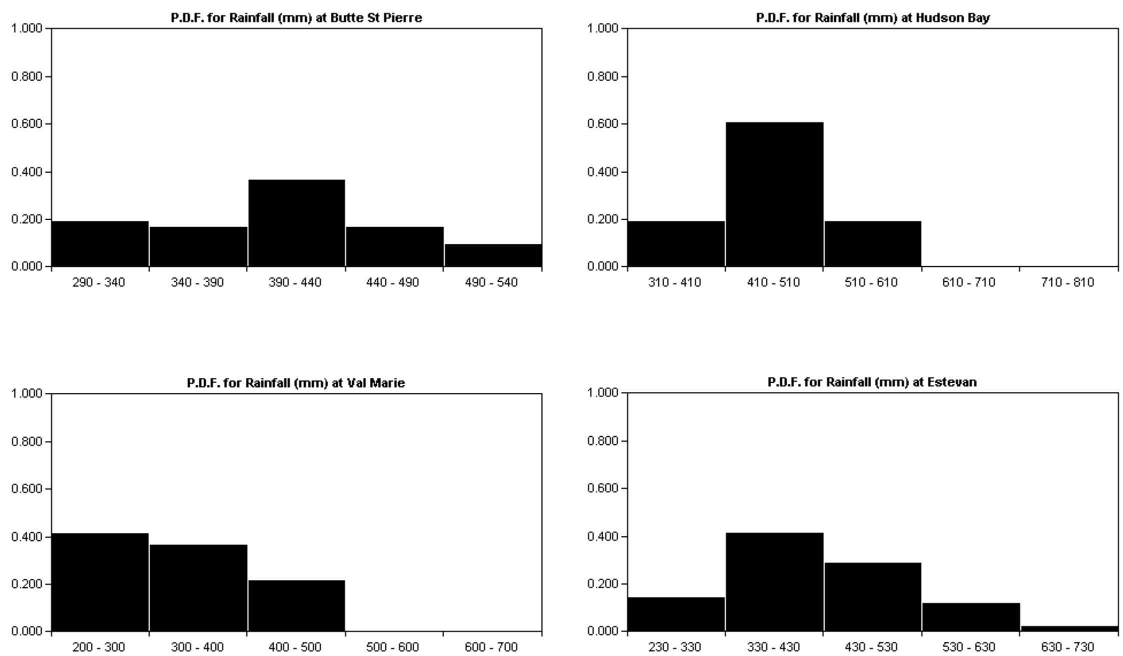

Figure 2. Probability distribution functions (PDF) for average annual precipitation (mm) at four locations in Saskatchewan 1960-2000.

Figure 3 presents the same information but in a cumulative distribution format. The cumulative distribution function (CDF) is a continuous function of probabilities (Y axis) from 0 to 1 for a continuous array of annual precipitation values (X axis) from the least to the most precipitation received between 1960 and 2000. Thus, the probability of receiving an amount of rain equal to the least value is 1 or 100% and more than the greatest amount is 0 or 0%. For example, figure 3 indicates that there is a 50% probability of an annual precipitation of at least 408mm at Butte St Pierre; 467mm at Hudson Bay; 323mm at Val Marie and 421mm at Estevan.

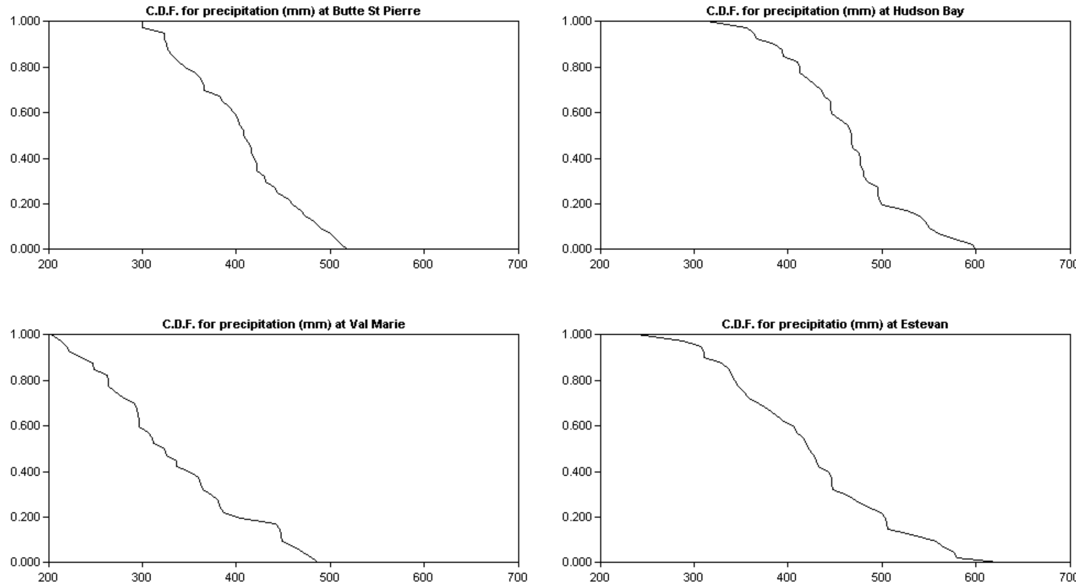

Figure 3. Cumulative distribution functions (CDF) for probability of precipitation at four locations in Saskatchewan 1960-2000.

Probability functions for long term average forage production

The comparative long-term average forage production at the four sites is shown in Figure 4. Data on the Y axis are available forage dry matter (kg/ha) and the X axis represents the mean for each month from January to December. The sudden drop in forage at the end of September represents the forage cut taken at that time. The amount of live forage remaining beyond September 30 represents remaining live forage in the crowns of the plants and not re-growth. GrassGro predicts the total above ground biomass. Zero biomass would indicate absolutely bare soil with no plant material present at all. Average productivity is obviously greater at Hudson Bay followed by Pierre St Butte, Estevan and Val Marie.

The probability distribution functions for maximum crested wheatgrass yields at the four locations are shown in Figure 5. Note that the probability distribution for Val Marie is 0 to 0.5 and 0 to 1 for all other locations. The probability of a maximum yield greater than 6,000 kg/ha for crested wheatgrass at Butte St Pierre is 44.1%; while there is a 59% probability of a maximum crested wheatgrass yield greater than 8,000 kg/ha at Hudson Bay; a 37% probability of a yield in excess of 5,000 kg/ha at Estevan and only a 26.8% probability of a yield greater than 4,000 kg/ha at Val Marie.

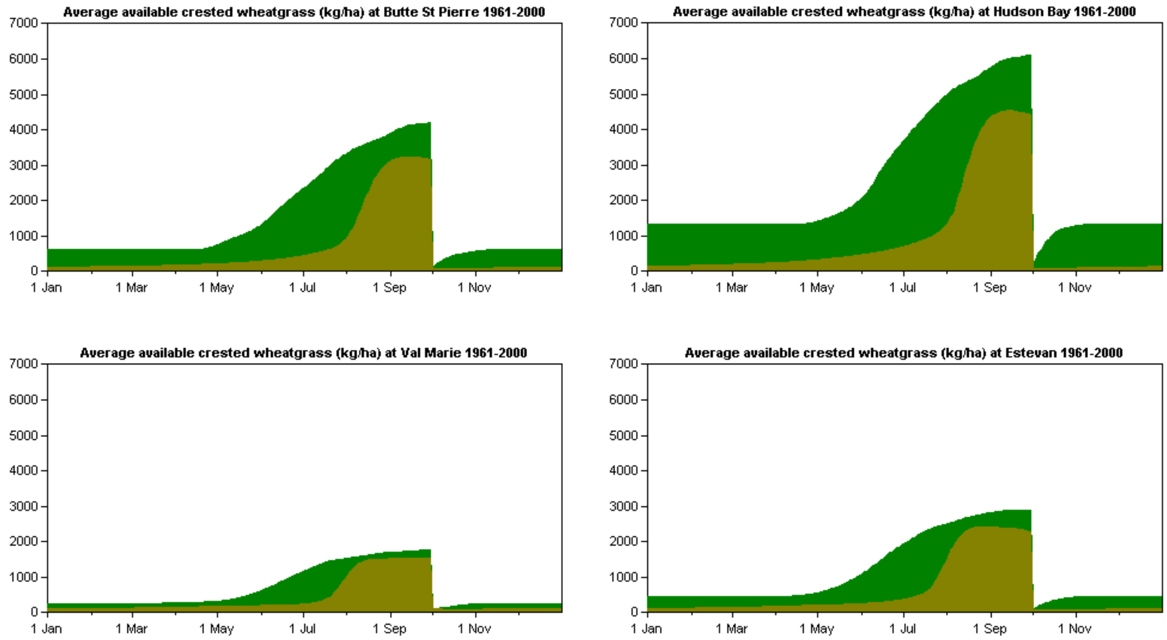

Figure 4. Average available live (green) and dead (olive) crested wheatgrass forage at four locations in Saskatchewan 1960-2000.

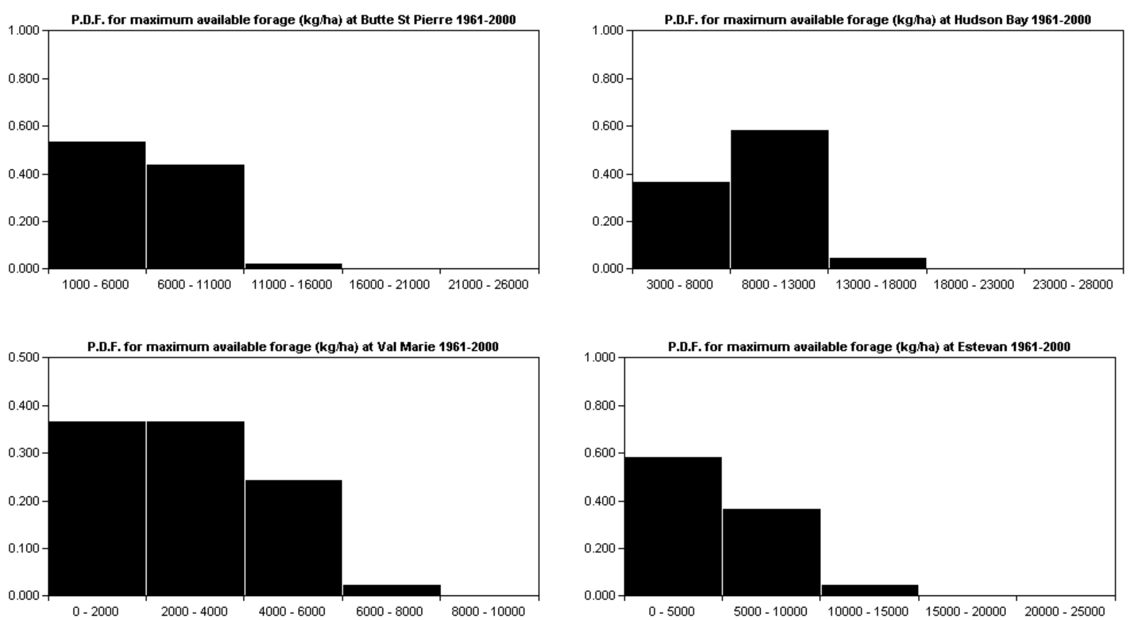

Figure 5. Probability distribution functions for maximum crested wheatgrass forage at four locations in Saskatchewan 1961-2000.

The cumulative distribution functions for maximum crested wheatgrass yields at the four locations are shown in Figure 6.

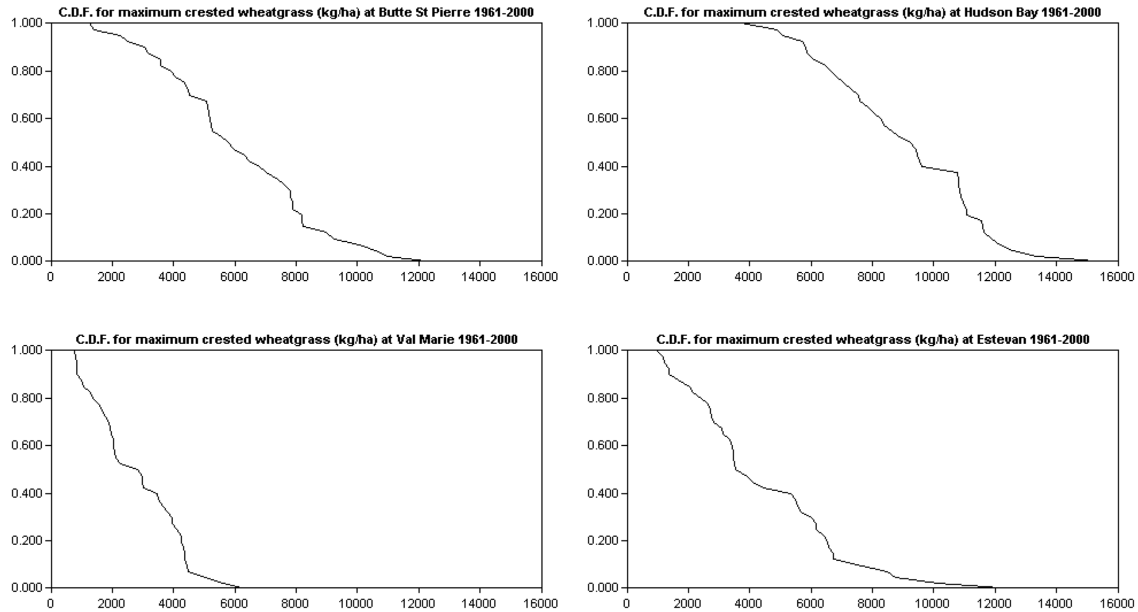

Figure 6. Cumulative distribution functions for maximum crested wheatgrass forage at four locations in Saskatchewan 1961-2000.

Environmental relationships with plant available water and growth

There is a 50% probability of crested wheatgrass reaching a maximum forage yield of 5,571kgDM/ha at Butte St Pierre; 9,207kgDM/ha at Hudson Bay; 2,809kgDM/ha at Val Marie and 3,528kgDM/ha at Estevan. The long-term average annual precipitation at Estevan (428mm) is intermediate to those at Hudson Bay (464mm) and Butte St Pierre (405mm) but maximum crested wheatgrass yield is less at Estevan than Butte St Pierre. There may be several reasons for this:

The precipitation is more favourably distributed for plant growth, particularly re-growth, at Butte St Pierre. This is demonstrated in Figure 7. Estevan receives more precipitation in the spring months of April, May and June but Butte St Pierre receives more precipitation in the summer months of July, August and September. This would enhance summer growth and re-growth at Butte St Pierre, especially if temperature was more favourable than at Estevan during those months. Figure 7 indicates that the daily maximum temperatures are lower at Butte St Pierre during these months. Figure 8 shows that this translates into more favourable plant growth temperatures, since crested wheatgrass is a cool season grass. Plant growth temperatures are about $3^{o}C$ lower during summer at Butte St Pierre. Figure 8 also shows that evaporation is lower at Butte St Pierre than Estevan. This reflects the lower temperatures and, in addition, the average wind speed at Butte St Pierre is 4.17m/sec (15.01km/h) and 5.28 m/sec (19.01km/h) at Estevan. All these factors translate into reduced plant available water at Estevan. This is shown in the left hand side graphs of Figure 9 which indicates that plant available moisture throughout the year is lower at Estevan than Butte St Pierre. The graphs on the right hand side of Figure 9 indicate that, on average, moisture becomes most limiting on July 27 at Estevan when it limits plant growth to 21.7% of its potential. In contrast, moisture becomes most limiting on August 18 at Butte St Pierre and only limits plant growth to 35.8% of its potential.

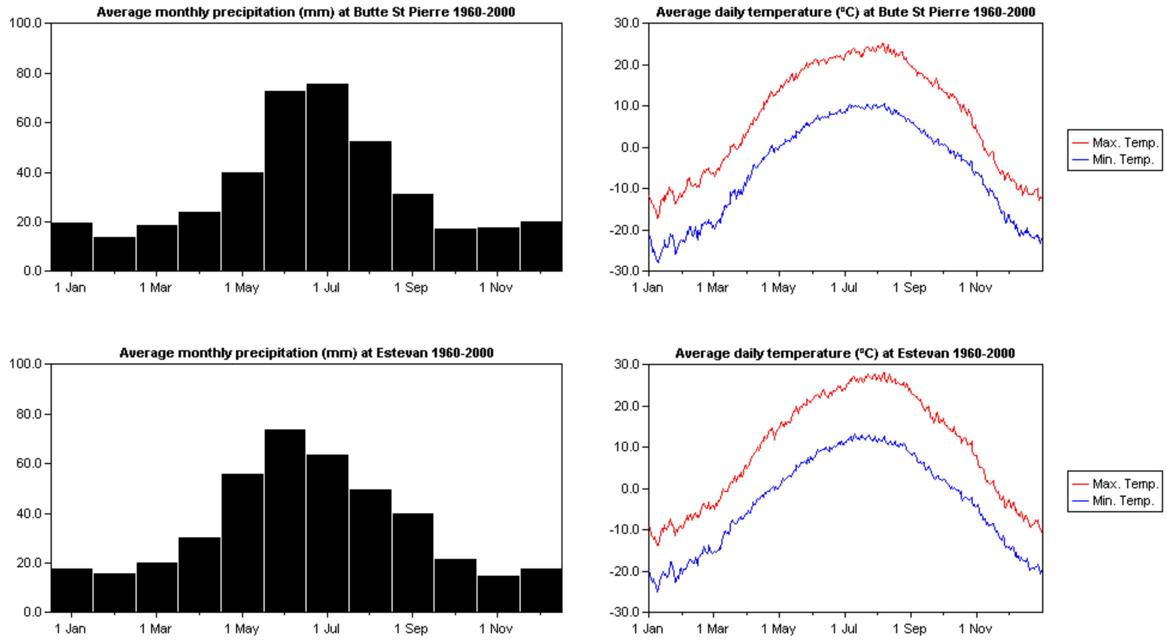

Figure 7. Average monthly precipitation and daily temperature at Butte St Pierre and Estevan 1960-2000.

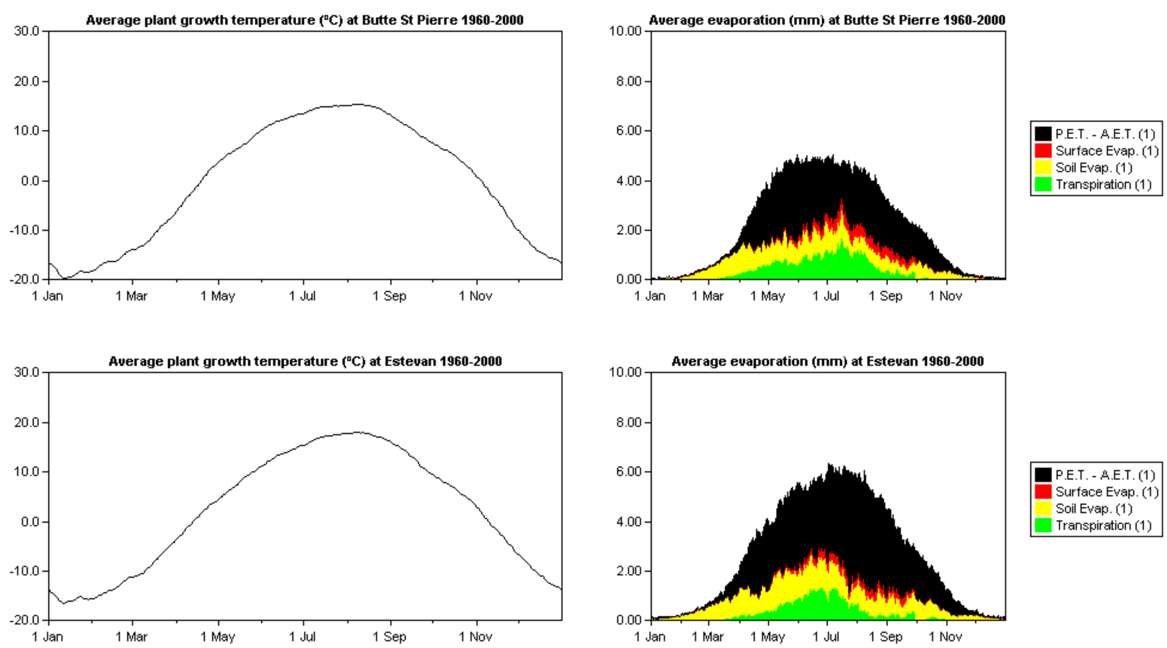

Figure 8. Average plant growth temperature and evaporation at Butte St Pierre and Estevan 1960-2000.

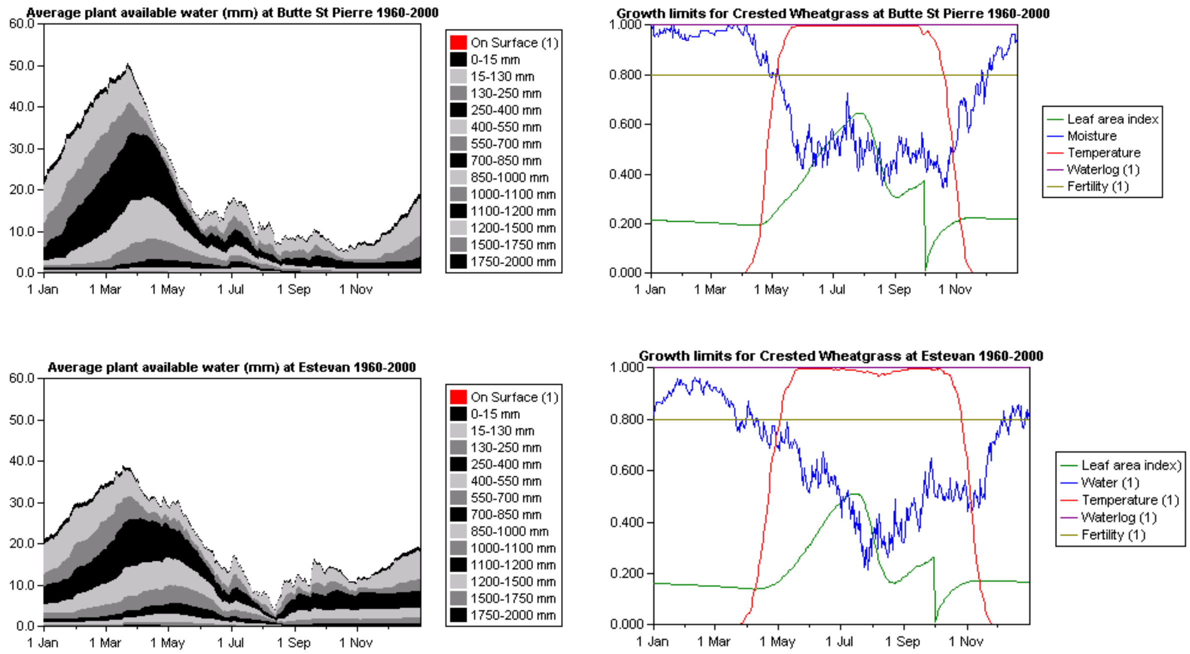

Figure 9. Average plant available water and limitations to growth of crested wheatgrass at Butte St Pierre and Estevan 1960-2000.

Conclusions

Any weather-based predictions of forage production should consider more than just rainfall during the growing season. Total precipitation and its distribution throughout the year and from previous years will have a large effect on soil moisture reserves during each growing season. In addition temperature and evaporation differences between locations will affect the growth of forages in any given season. Therefore the use of contiguous weather records involving precipitation, temperature and evaporation is important if forage production is to be accurately predicted.

If the methods reported in this report are to be adopted for forage insurance adjustment purposes it is recommended that the weather data be updated to include 2001 and 2002 and that updating be done each year at the conclusion of the pasture season. In addition, precipitation can vary widely over a short distance, particularly in summer when local storms are frequent and can provide substantial amounts of rain. Therefore, it may be necessary to expand the number of weather recording locations. However, it is recognized that the increased accuracy that this will provide must be balanced by the increased cost involved and the practical feasibility of greatly increasing the number of weather recording locations.

Acknowledgements

Funding for this project was provided by the Canada Saskatchewan Farm Livestock Water Program of the Prairie Farm Rehabilitation Association. I would like to acknowledge the Saskatchewan Crop Insurance Corporation, in particular Arlan Frick and Dale Wotherspoon, and SaskWater corporation, in particular Alex Banga, for their interest in the GrassGro decision support tool and for suggesting and championing this project.

Appendix 1. List of locations provided by Saskatchewan Crop Insurance Corporation.

Name	Province	Lat.	Long.
ANEROID	SK	4934	10718
ASSINIBOIA	SK	4944	10546
ATWATER	SK	5049	10213
BALCARRES	SK	5047	10337
BENSON	SK	4928	10301
BICKLEIGH	SK	5118	10824
BIGGAR	SK	5204	10759
BINSCARTH	MB	5035	10116
BROADVIEW	SK	5023	10241
BUTTE ST PIERRE	SK	5327	10912
CARLTON	SK	5248	10634
CODERRE	SK	5008	10622
COLD LAKE	AB	5424	11017
CORONACH SPC	SK	4903	10529
COTE	SK	5131	10148
CYPRESS HILLS	SK	4939	10931
DAHINDA	SK	4945	10500
DUVAL	SK	5110	10451
ELBOW 2	SK	5110	10633
ELKHORN 2 EAST	MB	4956	10112
ELROSE	SK	5108	10802
EMPRESS	AB	5057	11000
ESTEVAN	SK	4904	10300
FENWOOD	SK	5109	10304
FLIN FLON	MB	5441	10141
Harris	SK	5144	10735
HUDSON BAY	SK	5251	10232
HUMBOLDT	SK	5216	10507
INDIAN HEAD	SK	5032	10330
KELLIHER	SK	5115	10345
KINDERSLEY	SK	5128	10910
Last Mountain	SK	5125	10515
LEADER A	SK	5045	10930
LEROY	SK	5200	10439
LLOYDMINSTR A.	AB	5318	10959
MAFEKING	MB	5241	10106
MANOR	SK	4937	10206
MAPLE CREEK N.	SK	5000	10928
MCKAGUE2	SK	5235	10350
MEADOW LAKE	SK	5408	10831
MEDICINE HAT	AB	5001	11043
MELFORT CDA	SK	5249	10436
MELITA	MB	4920	10100
MOOSE JAW	SK	5020	10533
N. BATTLEFORD	SK	5246	10815
NIPAWIN	SK	5320	10400

Name	Province	Lat.	Long.
OUTLOOK PFRA	SK	5129	10703
OXBOW	SK	4913	10210
OYEN CAPPON	AB	5110	11031
PELLY	SK	5205	10152
PIERSON	MB	4911	10116
PRINCE ALBERT	SK	5313	10540
REGINA	SK	5026	10440
ROBLIN AUT	MB	5111	10122
ROCK POINT	SK	5109	10716
ROSETOWN EAST	SK	5134	10755
SASKATOON	SK	5210	10642
SCOTT CDA	SK	5222	10850
SHAUNAVON 2	SK	4944	10826
SWAN RIVER AUT	MB	5207	10114
SWIFT CURRENT	SK	5016	10744
THE PAS	MB	5358	10106
TUGASKE	SK	5053	10618
UNITY SOUTH	SK	5214	10912
VAL MARIE SE	SK	4904	10735
VIRDEN	MB	4951	10056
WASKESIU	SK	5355	10604
WATROUS	SK	5140	10528
WEST POPLAR RVR	SK	4900	10623
WEYBURN	SK	4939	10350
WILLMAR	SK	4925	10230
WYNYARD AUT	SK	5146	10412
YELLOW GRASS	SK	4948	10410
YORKTON	SK	5116	10228
TOTAL	74		
Additional stations			
SPIRITWOOD	SK		
ARTLAND	SK		
SHACKLETON	SK		
CLAYDON	SK		
LOON LAKE	SK		
MARGO	SK		
LAKE ALMA	SK		
TOTAL	81		

Appendix 2. Terms of reference for the project.

Attachment A:

TERMS OF REFERENCE
FOR PROFESSIONAL SERVICES

Project Title:

Model development (Grassgro) in support of a drought management strategy for livestock

Objectives

To provide the Saskatchewan Crop Insurance Corporation with a weather-based model and long-term historic weather data for evaluation as a tool for drought management strategy for livestock enterprises.

Background

The 2001 drought in Saskatchewan and Alberta has heightened awareness of the need for a risk management strategy for the livestock industries based on weather data. To be effective and fair, drought assistance should be based on local weather data and the level of assistance determined on a comparison between production during a drought year with the long-term average production for each location. Thus, if the level of production at one location is 50% below the long-term average for that location there is a greater need for assistance than that at another location where production was only 10% below long-term average. This can best be done with a weather-based model such as GrassGro.

Grassgro uses daily weather data such as precipitation, temperature, wind etc. to predict the growth of pasture and grazing cattle. GrassGro can be used in a general predictive capacity or it can be used in a very specific capacity. That is to say that GrassGro can predict the growth of any combination of 16 different native and tame grasses and legumes on soils of any of 12 different textures with or without the application of fertilizer, for hay production or pasture that is either ungrazed or grazed at any entered stocking rate and the growth of any class of cattle (cow, calf, steer, heifer) grazing that pasture. Or it can be used to determine the growth of a "standard" tame or native pasture grazed by a "standard" class of cattle. Regardless of how specific or general the information is, it is always relevant to the weather data at the particular location. The predictions from GrassGro have been validated and are very accurate.

The Saskatchewan Crop Insurance Corporation (SCIC) draws its weather information from 75 climate stations throughout Saskatchewan. Long-term daily weather data for each of 75 locations corresponding to the locations used by SCIC can be obtained from Environment Canada records to provide long-term average production data for each location. Daily weather data for 3 to 4 years leading up to and for the current year at any location can then be used to compare production for the current year with the long-term average and provide drought relief assistance based on need. It is important to include weather data for the 3-4 years leading up to the current year because this will affect the soil moisture carried over into the current year.

The Saskatchewan Crop Insurance Corporation has declared its interest in evaluating GrassGro as a tool for providing drought relief assistance. However, before that can be done it will be necessary to download daily weather data for 75 locations from Environment Canada and assemble them into the format required for use in GrassGro. This would require funding for the purchase cost of the weather data and salaries to assemble the large amount of data within a 3-month time frame. It will also be necessary to purchase software for copy protection of the GrassGro program. This is necessary so that an inventory can be kept of who is using the program so that updates can be provided when they become available.

Deliverables

The Saskatchewan Crop Insurance Corporation will receive a working copy of the GrassGro software for evaluation purposes. They will receive daily weather records from 1960 to 2000, or for as many years as Environment Canada have recorded data, for 75 locations throughout Saskatchewan in the required format for use in the evaluation of the GrassGro software. They will also receive sufficient long-term average production data computed for selected production options (hay, tame & native pasture etc.) from a wide enough range of locations to be able to evaluate the suitability of the software for their purposes. The potential exists to provide a complete library of long-term average production data for various options at each location following their evaluation of the software.

Representatives of Saskatchewan Crop Insurance Corporation will receive training in the use of the GrassGro software. If available, Saskatchewan Crop Insurance Corporation will also receive daily weather records for 2001 for as many months and locations that Environment Canada has assembled and verified records ready for downloading.

Completion

The project is to be completed by March 28, 2002.