Estimating carbon dioxide sequestration of Saskatchewan trees

Objective: measure the diameter of a tree and then estimate how much carbon dioxide it has sequestered (absorbed from the atmosphere) in its lifetime.

First, what is meant by carbon sequestration? This is the process of **collecting carbon in the form of carbon dioxide from the Earth's atmosphere**. Plants do this by the process of photosynthesis. What do you remember about photosynthesis? Think about how plants grow: what they use as energy (sunlight) and what they "breathe" in (CO_2) and out (O_2).

Did you know
there are over 60,000km of planted shelterbelts in Saskatchewan. That's like the distance from Saskatoon to Calgary, 100 times!

This activity focuses on tree species common to shelterbelts in Saskatchewan. Shelterbelts are rows of trees, planted strategically to slow down the wind. They are very common on farms in Saskatchewan, to shelter farmland. Six trees often found in shelterbelts are:

Caragana	Green Ash	Hybrid Poplar	Manitoba Maple	Scots Pine	White Spruce

While the main function of shelterbelts is to shelter land from the wind, **shelterbelts also take a lot of carbon out of the atmosphere**. A group of researchers from the University of Saskatchewan studied these six tree species to learn how much carbon dioxide they sequester over time. They observed many of each species to derive an equation for estimating first the trees' biomass and in turn its sequestered carbon. Visit shelterbelt-sk.ca to learn more about the researchers and their project.

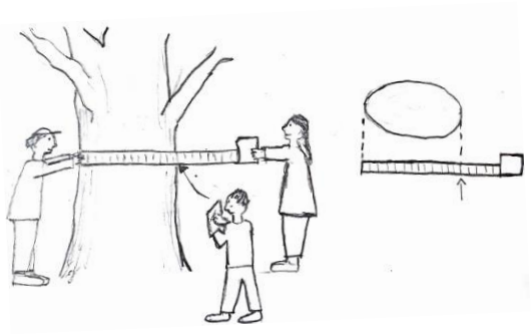
Using their equation, a measuring tape, and some math, you can do this estimating yourself. Here's how:

1. Identify the tree species. Circle the species that resembles the tree (photos page 7):

Caragana	Green Ash	Hybrid Poplar	Manitoba Maple	Scots Pine	White Spruce

2. Measure the tree diameter (at breast height).

Diameter = _____cm
diameter



3. Estimate the **age** of the tree using the DBH data table provided. _____ years old
age

4. What is the **Above Ground Biomass**?

   Researchers derived the following equation from their data. Factors *a* and *b* for each tree species are in the table below – use these inputs in to solve for Above Ground Biomass.

$$Above\ Ground\ Biomass = a \times DBH^b$$

Above Ground Biomass = _____ × _____ (_____) = _____kg
a *diameter* *b*

	Caragana	Green Ash	Hybrid Poplar	Manitoba Maple	Scots Pine	White Spruce
a	0.0284	0.20637	0.09142	0.29428	0.43264	0.0066
b	2.576	2.1217	2.3011	1.898	1.887	3.1832

5. What is the **Total Biomass**?

Total Biomass = _____ kg / _____ = _____ kg
Above Ground Biomass *Species Ratio*

What is ***Species Ratio***? Use the 'Species Ratio' table and the tree age to determine the *Species Ratio*. *Hint: if you don't know the age of the tree, use the measured diameter.*

Now we know the total biomass of the tree! This includes roots, stems, leaves, and the trunk! We can convert the total biomass value into carbon dioxide equivalent with a few quick calculations:

6. First, what is the **carbon** content of the tree?

Mass of carbon = _____ kg * 0.5 = _____ kg
Total Biomass

On average, about 50% of a tree's biomass is carbon.

7. How much carbon dioxide (**CO_2**) was sequestered (taken out of the atmosphere) by this tree?

Mass of CO_2 sequestered = _____ kg * $\frac{44\ CO_2}{12\ Carbon}$ = _____ kg
Mass of carbon

This is because for every CO_2 molecule, 12/44 of its weight is carbon. A CO_2 molecule weighs about 44 atomic mass units (amu) and a carbon atom weighs about 12 amu.

1 carbon atom		12 amu
+ 2 oxygen atoms	→	+(16 amu) x 2
1 CO_2 molecule		44 amu

Reference: Amichev, B. Y., Bentham, M. J., Kulshreshtha, S. N., Laroque, C. P., Piwowar, J. M., & Van Rees, K. C. (2016). Carbon sequestration and growth of six common tree and shrub shelterbelts in Saskatchewan, Canada. Canadian Journal of Soil Science, 97(3), 368-381.

Diametre at Breast Height (DBH) (cm)						
Age	Caragana	Green Ash	Hybrid Poplar	Manitoba Maple	Scots Pine	White Spruce
	0	0	0	0	0	0
1	0.2673	0.8134	0.4431	0.0393	0.1222	0.4122
2	3.4018	1.6068	1.1378	0.0738	0.4205	0.6355
3	5.6649	2.5461	2.3522	0.8134	0.9592	0.9171
4	7.5075	3.5745	4.0350	3.3838	1.7740	1.2862
5	9.0890	4.6125	6.0184	5.7351	2.7858	1.7541
6	10.5282	5.6673	8.2419	7.6763	3.9385	2.3624
7	11.7352	6.6695	10.5012	9.2898	5.0897	3.1037
8	12.8326	7.6501	12.8122	10.7631	6.2376	4.0265
9	13.8074	8.5627	15.0228	12.0717	7.3257	5.1122
10	14.7047	9.4263	17.1379	13.2801	8.3633	6.3646
11	15.5309	10.2411	19.1177	14.4001	9.3454	7.7427
12	16.2960	11.0068	20.9589	15.4422	10.2650	9.1801
13	17.0272	11.7479	22.7203	16.4453	11.1608	10.6601
14	17.7139	12.4472	24.3680	17.3909	12.0067	12.0583
15	18.3726	13.1200	25.9389	18.3012	12.8214	13.3561
16	19.0080	13.7704	27.4431	19.1839	13.6131	14.5443
17	19.6085	14.3854	28.8523	20.0216	14.3649	15.6037
18	20.1911	14.9817	30.2066	20.8376	15.0960	16.5717
19	20.7564	15.5604	31.5094	21.6330	15.8109	17.4619
20	21.2913	16.1076	32.7315	22.3888	16.4879	18.2594
21	21.8236	16.6517	33.9374	23.1442	17.1622	19.0142
22	22.3309	17.1699	35.0776	23.8671	17.8105	19.7071
23	22.8340	17.6837	36.2004	24.5875	18.4540	20.3655
24	23.3142	18.1733	37.2638	25.2775	19.0704	20.9727
25	23.7817	18.6498	38.2926	25.9520	19.6719	21.5460
26	24.2287	19.1049	39.2697	26.5990	20.2497	22.0795
27	24.6772	19.5616	40.2454	27.2513	20.8293	22.6000
28	25.1225	20.0151	41.2094	27.9016	21.4047	23.1032
29	25.5462	20.4460	42.1211	28.5220	21.9563	23.5742
30	25.9708	20.8781	43.0314	29.1467	22.5080	24.0348
31	26.3851	21.2997	43.9159	29.7585	23.0493	24.4775
32	26.7800	21.7015	44.7558	30.3437	23.5711	24.8960
33	27.1692	22.0976	45.5807	30.9225	24.0838	25.2999
34	27.5533	22.4884	46.3919	31.4954	24.5906	25.6926
35	27.9322	22.8739	47.1894	32.0624	25.0922	26.0750
36	28.3036	23.2520	47.9692	32.6202	25.5867	26.4466
37	28.6499	23.6039	48.6928	33.1408	26.0475	26.7878
38	28.9920	23.9517	49.4063	33.6569	26.5042	27.1216
39	29.3303	24.2956	50.1098	34.1684	26.9573	27.4488
40	29.6719	24.6432	50.8191	34.6867	27.4135	27.7744
41	29.9991	24.9763	51.4975	35.1847	27.8549	28.0860
42	30.3285	25.3118	52.1790	35.6874	28.3002	28.3969
43	30.6428	25.6322	52.8283	36.1686	28.7252	28.6904
44	30.9617	25.9573	53.4859	36.6579	29.1591	28.9873
45	31.2706	26.2723	54.1218	37.1330	29.5791	29.2719
46	31.5825	26.5909	54.7638	37.6147	30.0053	29.5580
47	31.8906	26.9058	55.3971	38.0917	30.4272	29.8388
48	32.1876	27.2095	56.0068	38.5527	30.8349	30.1075
49	32.4780	27.5065	56.6019	39.0041	31.2337	30.3685
50	32.7712	27.8066	57.2024	39.4615	31.6363	30.6297
51	33.0613	28.1038	57.7959	39.9149	32.0350	30.8864
52	33.3451	28.3947	58.3761	40.3598	32.4258	31.1361
53	33.6184	28.6750	58.9341	40.7890	32.8043	31.3760
54	33.8927	28.9563	59.4936	41.2206	33.1855	31.6162
55	34.1643	29.2351	60.0471	41.6489	33.5639	31.8530
56	34.4286	29.5067	60.5857	42.0668	33.9334	32.0828
57	34.6940	29.7796	61.1260	42.4873	34.3042	32.3119
58	34.9533	30.0465	61.6539	42.8992	34.6686	32.5356
59	35.2149	30.3160	62.1862	43.3157	35.0360	32.7599
60	35.4738	30.5828	62.7126	43.7287	35.3997	32.9806

Species Ratios						
Age	Caragana	Green Ash	Hybrid Poplar	Manitoba Maple	Scots Pine	White Spruce
0	0	0	0	0	0	0
1	0.5000	0.5000	0.5000	0.5000	0.5000	0.3333
2	0.8310	0.6575	0.6652	0.2166	0.3140	0.4691
3	0.8702	0.7090	0.7144	0.4710	0.4031	0.5271
4	0.8823	0.7327	0.7363	0.6586	0.4773	0.5565
5	0.8884	0.7464	0.7485	0.7058	0.5313	0.5759
6	0.8923	0.7561	0.7573	0.7281	0.5706	0.5902
7	0.8951	0.7630	0.7629	0.7416	0.6002	0.6024
8	0.8973	0.7690	0.7679	0.7522	0.6238	0.6129
9	0.8992	0.7746	0.7728	0.7612	0.6436	0.6227
10	0.9008	0.7797	0.7772	0.7689	0.6607	0.6316
11	0.9023	0.7846	0.7816	0.7760	0.6761	0.6402
12	0.9037	0.7893	0.7858	0.7824	0.6902	0.6486
13	0.9050	0.7939	0.7900	0.7885	0.7029	0.6565
14	0.9063	0.7982	0.7941	0.7942	0.7148	0.6648
15	0.9075	0.8024	0.7980	0.7995	0.7259	0.6733
16	0.9086	0.8065	0.8019	0.8045	0.7362	0.6821
17	0.9097	0.8105	0.8058	0.8094	0.7460	0.6911
18	0.9107	0.8144	0.8096	0.8140	0.7553	0.7001
19	0.9118	0.8182	0.8132	0.8184	0.7639	0.7090
20	0.9128	0.8220	0.8170	0.8227	0.7724	0.7181
21	0.9137	0.8255	0.8205	0.8267	0.7801	0.7266
22	0.9147	0.8290	0.8240	0.8307	0.7875	0.7351
23	0.9156	0.8324	0.8274	0.8344	0.7944	0.7432
24	0.9165	0.8358	0.8308	0.8381	0.8012	0.7513
25	0.9173	0.8390	0.8341	0.8416	0.8077	0.7591
26	0.9182	0.8423	0.8374	0.8451	0.8140	0.7669
27	0.9191	0.8454	0.8406	0.8484	0.8198	0.7740
28	0.9199	0.8483	0.8436	0.8515	0.8251	0.7808
29	0.9207	0.8513	0.8466	0.8545	0.8305	0.7875
30	0.9215	0.8541	0.8495	0.8574	0.8354	0.7938
31	0.9222	0.8568	0.8523	0.8603	0.8401	0.7998
32	0.9230	0.8596	0.8552	0.8632	0.8448	0.8059
33	0.9238	0.8623	0.8580	0.8659	0.8492	0.8117
34	0.9245	0.8649	0.8607	0.8686	0.8535	0.8171
35	0.9253	0.8674	0.8633	0.8711	0.8574	0.8223
36	0.9260	0.8699	0.8658	0.8735	0.8612	0.8272
37	0.9267	0.8724	0.8684	0.8761	0.8653	0.8325
38	0.9275	0.8748	0.8710	0.8785	0.8691	0.8375
39	0.9282	0.8772	0.8734	0.8808	0.8727	0.8421
40	0.9289	0.8793	0.8756	0.8830	0.8759	0.8463
41	0.9296	0.8816	0.8779	0.8852	0.8791	0.8505
42	0.9303	0.8836	0.8801	0.8872	0.8821	0.8543
43	0.9309	0.8858	0.8823	0.8894	0.8851	0.8583
44	0.9316	0.8877	0.8844	0.8913	0.8878	0.8617
45	0.9322	0.8897	0.8864	0.8932	0.8905	0.8652
46	0.9329	0.8915	0.8883	0.8950	0.8929	0.8684
47	0.9335	0.8933	0.8902	0.8967	0.8951	0.8713
48	0.9341	0.8951	0.8921	0.8985	0.8975	0.8745
49	0.9347	0.8969	0.8940	0.9003	0.8999	0.8775
50	0.9353	0.8986	0.8957	0.9019	0.9020	0.8802
51	0.9359	0.9002	0.8974	0.9035	0.9040	0.8829
52	0.9365	0.9018	0.8991	0.9050	0.9060	0.8855
53	0.9371	0.9035	0.9008	0.9066	0.9081	0.8882
54	0.9377	0.9050	0.9024	0.9081	0.9100	0.8906
55	0.9382	0.9065	0.9040	0.9096	0.9118	0.8929
56	0.9388	0.9080	0.9056	0.9110	0.9136	0.8952
57	0.9394	0.9094	0.9070	0.9124	0.9153	0.8973
58	0.9399	0.9108	0.9085	0.9137	0.9169	0.8994
59	0.9404	0.9121	0.9099	0.9150	0.9184	0.9013
60	0.9410	0.9134	0.9112	0.9162	0.9198	0.9032

CURRICULUM CONNECTIONS

Grade 9 Mathematics N9.1 Demonstrate (concretely, pictorially, and symbolically) understanding of powers with integral bases (excluding base 0) and whole number exponents including: representing using powers; evaluating powers; powers with an exponent of zero; solving situational questions. **Science AE9.1** Distinguish between physical and chemical properties of common substances, including those found in household, commercial, industrial, and agricultural applications.
Level 10 Workplace and Apprenticeship Mathematics 10 WA10.1 Demonstrate understanding of the preservation of equality including solving problems that involve the manipulation and application of formulas related to: perimeter; area; the Pythagorean Theorem; primary trigonometric ratios; income. **WA10.5** Demonstrate using concrete and pictorial models, and symbolic representations, understanding of area of 2-D shapes and surface area of 3-D objects including units in SI and Imperial systems of measurement. **Science SCI10-CD1** Assess the implications of human actions on the local and global climate and the sustainability of ecosystems.
Level 20 Workplace and Apprenticeship Mathematics 20 WA20.1 Expand and apply understanding of the preservation of equality including solving problems that involve the manipulation and application of formulae for volume and capacity, surface area, slope and rate of change, simple interest, and finance charges. **WA20.3** Extend and apply understanding of surface area, volume, and capacity using concrete and pictorial models and symbolic representations (SI or imperial units of measurement). **Environmental Science 20 ES20-AH1** Assess the impact of human activities on indoor and outdoor air quality and the need for regulations and mitigating technologies to minimize risks to human health. **ES20-AH2** Analyze the production, reliability and uses of geoscience data to investigate the effects of a changing climate on society and the environment. **ES20-TE2** Examine the role plants play in an ecosystem, including the ways in which humans use plants.
Level 30 Earth Science ES30-AH1 Analyze the composition of Earth's atmosphere and factors that influence changes in the composition in the short and long term.

Caragana

Photo by the Shelterbelt DSS

Green Ash

Photo by the Shelterbelt DSS

Hybrid Poplar

Photo by the Shelterbelt DSS

Manitoba Maple

Photo by USDA

Scots Pine

Photo by the Shelterbelt DSS

White Spruce

Photo by the Shelterbelt DSS