OLD BLACK HILLS PONDEROSA PINES TELL A STORY

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ABSTRACT

A single ponderosa pine tree found in the central Black Hills of South Dakota revealed its age of more than 700 years by its tree rings taken from coring in 1992. The purpose of this study was to examine historic climatic patterns from the 13th century through most of the 20th century as inferred from ring widths of this and other nearby trees. The steep, rocky site where this tree was found helped this tree and its cohorts survive fires and other damaging agents.

Our analysis indicated that both dry and wet spells of longer duration and magnitude than the 1930's drought have occurred previously. For example, since 1600, the 1930's "dust bowl" drought ranks 4th in severity. Further, if additional evidence supports the single tree record, the 1930's drought may be of even less significance.

INTRODUCTION

The use of dendrochronological techniques to study drought history of regions has been available much of this century. Two of the pioneers include A.E. Douglass (1914 and 1919) and H.C. Fritts (1976). Meko (1982) used these techniques to study drought history of the western Great Plains (1640-1977). He suggested that the severity of the 1930's drought was over-shadowed by droughts of the 1750's, 1820's, and 1860's. The purpose of the present study is to get a glimpse of even earlier droughts using tree core data collected in 1992 and to explore their severity and periodicity, if any, and to extend the earlier work of DeGaetano and Miller (1990).

DATA ANALYSIS

Two tree-ring chronologies of ponderosa pine (*Pinus ponderosa*) from the central and southern Black Hills of South Dakota gathered during 1991-1992 are examined. The collection, development, and overall reliability of the data are described in Sieg *et al.* (1996). The oldest tree dates to 1281 A.D., while the most reliable period of the chronology covers approximately 400 years, starting from 1600, when at least five independent tree-ring samples were available. The data set consists of detrended tree-ring widths from 1281-1991.

There is more variability of the tree-ring widths in the first few hundred years of the chronology when compared to the latter half of the chronology due in part to the gradual increase in sample size. In order to account for variability due to sample size, the tree-ring time series was incrementally standardized from 1281-1393, 1394-1597, 1598-1681, 1682-1768, and 1769-1991. Each sub-period contained l-2, 3-4, 5-8, 9-15, and 16-22 tree samples, respectively. The choice of the sub-periods was based both on having close to 100 years in each epoch and subjective consideration of the variability in the original time series. After this operation was performed, the collective time series was standardized again to ensure continuous Gaussian characteristics. A similar procedure has also been performed on the Southern Oscillation index data to account for differences in monthly variability (Wilks 1995).

Similar to other studies (Stockton and Meko 1983; DeGaetano and Miller 1990; Sieg *et al.* 1996), precipitation from September of the year prior to tree growth to August of the year of tree growth was chosen to correlate with tree-ring width. Precipitation data were obtained from: (i) Hill City (1956-1990, in the central Black Hills); (ii) Rapid City (1889-1991, along the eastern Black Hills); and (iii) a climate region both surrounding the Black Hills and including part of the southern Black Hills (1889-1990, cluster "C" in Figure 8 of Bunkers *et al*. (1996) — herein denoted BLKHLS).

RESULTS AND DISCUSSION

The one-year correlations were nearly identical among the three precipitation records and the tree-ring widths, but the five-year average (precipitation and tree-ring width) correlations were notably stronger using both the Rapid City and BLKHLS region precipitation (Table 1). The one-year correlation coefficients are comparable to those found in the previous studies mentioned above. The relationship between the September to August precipitation and the tree ring indices suggests that the tree-ring data can be used as a proxy for seasonal precipitation for the period of record with precipitation data (e.g., Figs. la, b). Extrapolation to earlier years assumes: (1) a similar growth-precipitation relationship, and (2) a similar role (or lack thereof) of temperature dependence. The extrapolation necessarily includes years when temperature extremes could have played a significant role during the Little Ice Age, 1550-1870 (Pielou, 1992).

Other studies typically reconstruct the annual (September-August) precipitation via multiple linear regression using a combination of the tree growth

Table 1. Correlation between September-August precipitation and tree-ring width.

	Hill Citv	Rapid Citv	BLKHLS Region
1-year	0.56	0.56	0.53
5-year	0.59	0.70	0.70

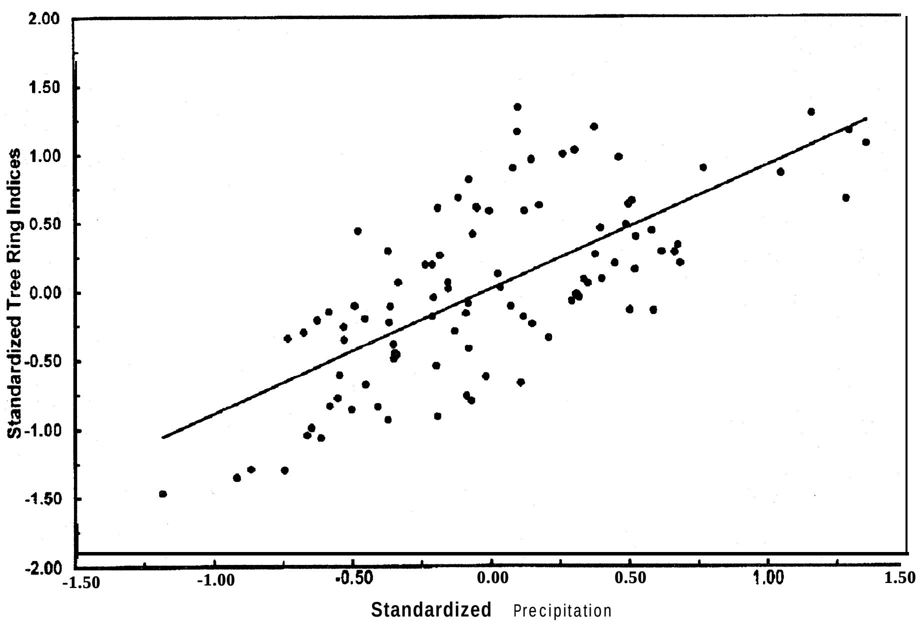

Figure 1a. Scatter plot of the 5-year September-August, Rapid City standardized precipitation versus the 5-year standardized tree-ring indices.

during year T-l, T, and T+1. Yet other studies have reconstructed the Palmer drought severity index (PDSI) using similar tree-growth variables as predictors (Stable and Cleaveland 1988). In the current study, no significant additional information could be gained by performing a multiple linear regression such as these for the period of record; rather, the annual (September-August) precipitation was best explained solely by tree growth during year T (i.e., a simple correlation). Furthermore, we have examined the 5-year-average annual (September-August) precipitation since this has the advantage of highlighting periods of extended drought, and also benefits from the stronger correlations (Table 1, Fig. lb). This study also differs from previous studies in that we examine the standardized precipitation, and not the actual precipitation. Since September-August precipitation from the selected sites is approximately Gaussian, this facilitates interpretation of the twice-standardized tree-ring widths during each year in terms of probability. Recently, a drought index (the Stan-

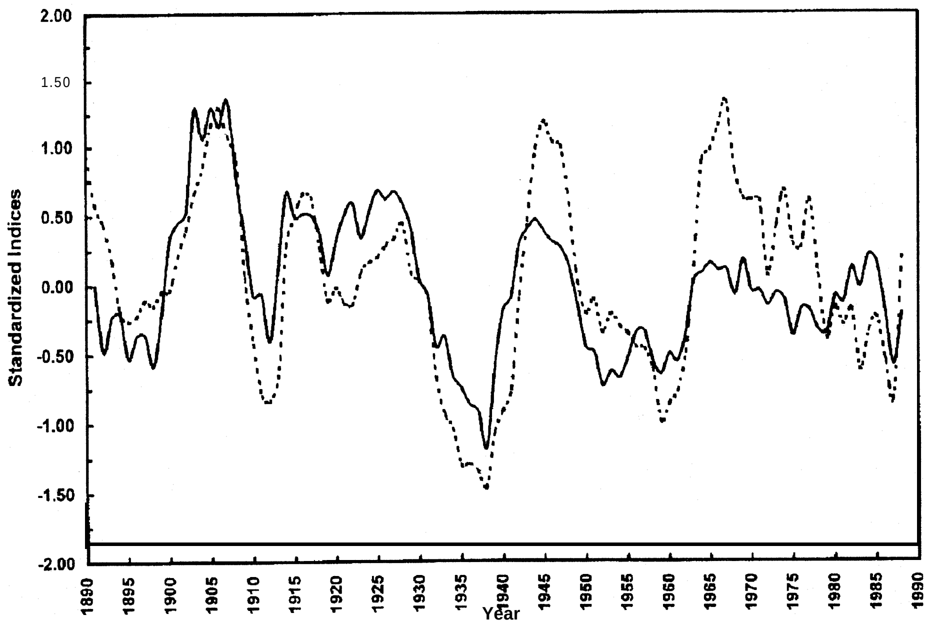

Figure lb. Plot of 5-year, September-August Rapid City standardized precipitation data (dashed) and the 5-year standardized tree-ring indices (solid).

dardized Precipitation Index) has been developed which takes an approach similar to ours in monitoring and assessing drought (Hayes *et al.* 1999).

The twice standardized tree ring index values are shown in Figure 2 (a table of actual values is given in Appendix A). The number of trees in the sample is also indicated in Appendix A, which must be considered when discussing the climatic features suggested by this chronology.

A spectral analysis of the tree-ring chronology is shown in Figure 3. The search for cycles that reappear in time revealed 40% of the variance is explained by high-frequency (<10

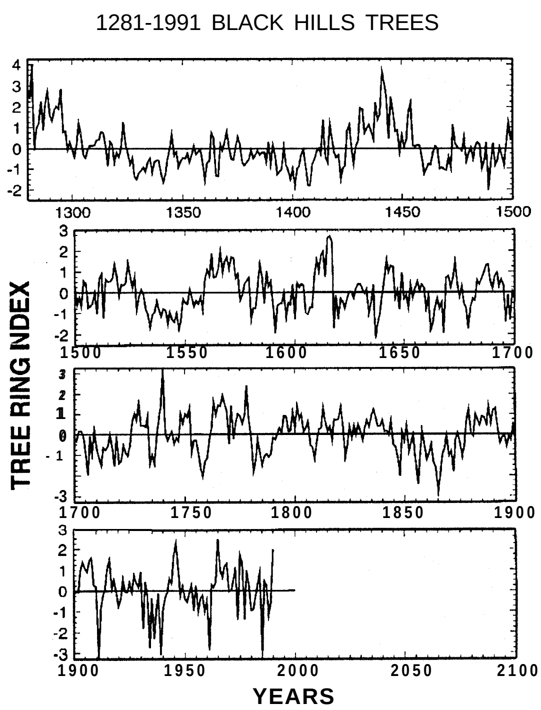

Figure 2. Twice standardized tree ring indices shown as standard deviation from the mean for years 1281-1991.

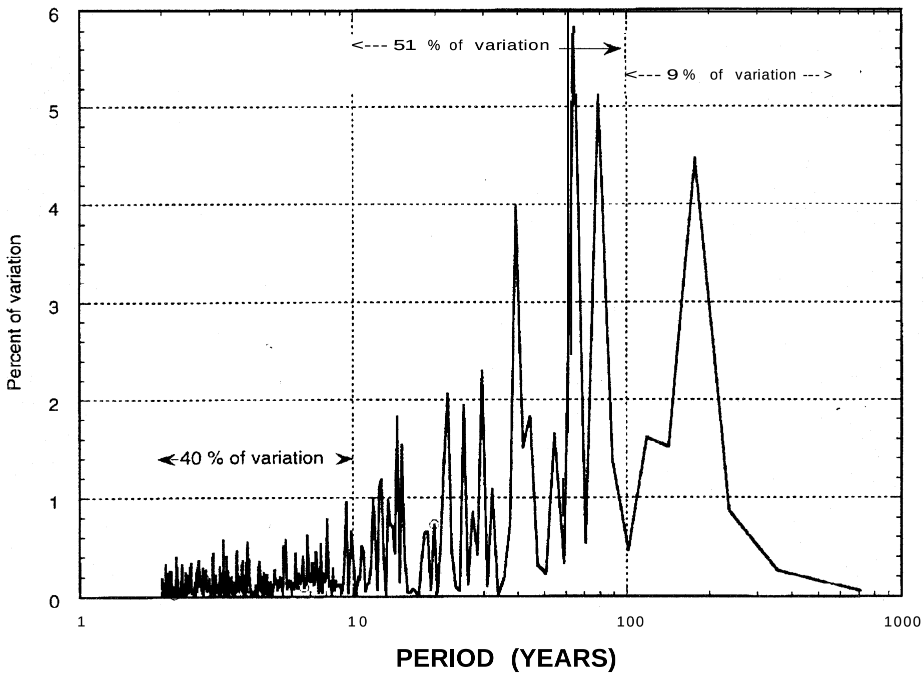

Figure 3. Spectral analysis representation of the tree-ring chronology given in Appendix A.

years) noise (i.e. year to year deviations); and 51% of the variance is distributed over periods from 10-100 years. Of note is the absence of an 11-year cycle which would correspond to the sunspot cycle. Other cycles, although weak, are 22-year (3%), 26-year (<3%), 29-year (>3%), 39-year (5%), 44-year (<3%), 54-year (<3%), 64-year (6%), 79-year (7%), and 178-year (9%). All of these values are very weak in their explanation of periodicity of the variability in the tree-ring indices. We cannot say with any confidence that there exists any relationship between these periodicities and other physical or astronomical indicators.

The early years of the single tree showed good growth as might be expected of a relatively young ponderosa pine, but the weather was most likely very favorable for its early development given its relatively large tree-ring indices (Fig. 2). In the early 1300's the tree appeared well established, but its narrow rings suggest that conditions were not favorable for growth the first one hundred years. This agrees with other regional studies by Bryson and Murray (1977) which showed a general drying of the climate across the South Dakota-Iowa region as revealed by changes in living habits of the indigenous peoples, especially in northwest Iowa. The tree-ring data shown in Figure 2 may reflect an extended dry period from 1300 to 1424 (ninety years of index values were <0.00). Bryson and Baerreis (1968) suggest this dry period was likely associated with an expansion in the westerlies in the northern hemisphere as a whole, thus restricting the flow of Gulf of Mexico moisture flow northward into the Dakotas and Iowa. A subsequent change to more favorable climate likely occurred in the 1400's, about 1430's through 1450 or so, as shown by the tree-ring indices from this one tree. Additional tree-ring samples extending back into the 1200's are needed to determine if these trends are consistent throughout the region.

Later on, the period 1792 through 1844 was a 5-decade period of lesser variability in the severity of wet and dry years; it appeared as the most stable climate period in this 711-year record- *a sign of little variability in the general circulation over the region.* 1845-1877 was a period with extreme drought, as has been noted in other studies across the Great Plains (e.g., Woodhouse and Overpeck 1998).

Finally, the remainder of the graph follows closely the known official precipitation record as measured at Rapid City beginning in 1888. It is characterized by a slight dry period from 1893 through 1902, a wet spell through 1910, a drought from 1911-1913, the major drought of the 1930's, another downward trend in growth in the 1950's and yet another in 1988 which corresponds with the occurrence of several major forest fires in the Black Hills.

Table 2 shows the rank, estimated magnitude, and duration of the major dry and wet spells as suggested by the examination of this tree ring chronology. The magnitude of the droughts and wet spells are estimated by summing the consecutive negative and consecutive positive standardized index values, respectively, in the years shown. This summary helps us to put recent droughts in perspective. Since 1600, the 1930's "dust bowl" drought ranks 4th (note that using this summation of indices method of estimated magnitude of the drought, the 1930's was about 50% as severe as the worst drought); the 1950's drought ranked 12th. The 15-year drought associated with "The Great American Desert" period, 1859-1873, ranked 3rd.

Should additional samples support the record inferred by the single tree extending into the 1200's, the 21-year dry period from 1531 through 1551 could be the most severe drought in this 711-year chronology. By comparison, the 1930's "dust bowl" drought of the present century ranked 7th.

SUMMARY

The data from the Black Hills trees suggest dry and wet periods of similar magnitude to the 1930's drought have occurred since the late 1200's. One measure of drought indicates that the 1933-1942 period was only 50 percent of the magnitude of the 1531-1551 period, and ranks seventh overall. Caution should be used, however, when interpreting the early part of the tree-ring record as a sample size of one tree is likely not adequate to infer climatic patterns, and variables other than precipitation may be influencing the growth.

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Table 2. Duration and magnitude estimates of 15 dry and 15 wet spells.

	Dry Periods*				Wet Periods**			
Rank	Sum of indices	Years	No. Years	% of MAX	Sum of indices	Years	No. Years	% of MAX
1	-20.15	1531-1551[a]	21	100.0	29.03	1429-1448[a]	20	100.0
2	-18.30	1325-1344[a]	20	90.8	23.3	1284-1297[a]	14	80.3
3	-16.62	1859-1873	15	82.5	19.15	1559-1574[a]	16	66.0
4	-14.70	1397-1411[a]	15	73.0	15.57	1609-1617	9	53.6
5	-13.25	1710-1725	16	65.8	10.37	1762-1769	8	35.7
6	-10.34	1780-1791	12	51.3	9.14	1882-1892	11	31.5
7	-10.08	1933-1942	10	50.0	8.92	1683-1695	12	30.0
8	-8.76	1753-1761	9	43.5	8.15	1792-1806	15	28.1
9	-8.40	1660-1668	9	44.7	7.89	1903-1910	8	27.2
10	-6.48	1580-1598[a]	9	32.2	7.57	1962-1969	8	26.1
11	-5.98	1852-1857	6	29.7	7.09	1773-1779	7	24.4
12	-5.96	1956-1961	6	29.6	6.13	1832-1842	11	21.1
13	-5.44	1467-1472[a]	6	27.0	6.10	1726-1733	8	21.0
14	-5.30	1377-1388[a]	12	26.3	5.97	1943-1947	5	20.6
15	-5.00	1637-1640	4	24.8	5.66	1641-1645	5	19.5

* "harrow rings" ** "wide rings"
[a]sample size <5 trees, and is likely not adequate to reliably infer precipitation patterns.

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APPENDIX A

Twice-Standardized Tree-Ring Indices

NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2
1	1281	2.40	1	1321	-0.42	1	1361	-0.72
"	1282	4.02	"	1322	0.07	"	1362	-0.64
"	1283	-0.09	"	1323	1.25	"	1363	0.74
"	1284	0.95	"	1324	0.20	"	1364	0.50
"	1285	1.20	"	1325	-0.22	"	1365	-1.33
"	1286	2.28	"	1326	-0.78	2	1366	-1.39
"	1287	0.87	"	1327	-0.48	"	1367	0.18
"	1288	2.16	"	1328	-1.39	"	1368	-0.13
"	1289	2.73	"	1329	-1.51	"	1369	0.28
"	1290	1.58	"	1330	-1.20	"	1370	0.78
"	1291	1.31	"	1331	-1.08	"	1371	0.04
"	1292	1.85	"	1332	-0.93	"	1372	-0.54
"	1293	2.03	"	1333	-1.15	"	1373	-0.58
"	1294	1.90	"	1334	-0.69	"	1374	0.00
"	1295	2.86	"	1335	-0.49	"	1375	0.54
"	1296	0.78	"	1336	-1.19	"	1376	0.19
"	1297	0.82	"	1337	-0.68	"	1377	-0.72
"	1298	-0.06	"	1338	-0.60	"	1378	-0.85
"	1299	0.30	"	1339	-0.60	"	1379	-0.72
"	1300	-0.05	"	1340	-1.23	"	1380	-0.57
"	1301	-0.41	"	1341	-1.66	"	1381	-0.08
"	1302	0.21	"	1342	-1.26	"	1382	-0.51
"	1303	1.19	"	1343	-0.52	"	1383	-0.34
"	1304	0.65	"	1344	-0.04	"	1384	-0.13
"	1305	-0.32	"	1345	0.68	"	1385	-0.32
"	1306	-0.46	"	1346	-0.35	"	1386	-0.20
"	1307	-0.02	"	1347	-0.19	"	1387	-0.19
"	1308	0.13	"	1348	-0.94	"	1388	-0.67
"	1309	0.13	"	1349	-0.66	"	1389	0.31
"	1310	0.14	"	1350	-0.46	"	1390	-0.80
"	1311	0.40	"	1351	-0.50	"	1391	0.16
"	1312	0.40	"	1352	-0.26	"	1392	-0.36
"	1313	0.78	"	1353	-0.69	3	1393	-1.28
"	1314	0.75	"	1354	-0.33	"	1394	-1.16
"	1315	0.16	"	1355	0.11	"	1395	-1.03
"	1316	-0.88	"	1356	-0.29	"	1396	0.05
"	1317	0.32	"	1357	-0.16	"	1397	-0.84
"	1318	0.21	"	1358	-0.04	"	1398	-1.09
"	1319	-0.69	"	1359	-0.72	"	1399	-1.53
"	1320	-0.20	"	1360	-1.57	"	1400	-1.03

NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2
3	1401	-1.83	4	1446	1.76	4	1491	0.24
"	1402	-1.02	"	1447	0.81	"	1492	-0.84
"	1403	-0.89	"	1448	0.87	"	1493	-0.65
"	1404	-0.28	"	1449	-0.17	"	1494	0.05
"	1405	-0.07	"	1450	0.62	"	1495	-0.34
"	1406	-0.95	"	1451	0.08	"	1496	-0.83
"	1407	-1.83	"	1452	0.41	"	1497	0.23
"	1408	-1.83	"	1453	1.70	"	1498	1.23
"	1409	-0.82	"	1454	2.16	"	1499	0.42
"	1410	-0.54	"	1455	0.13	"	1500	0.38
"	1411	-0.15	"	1456	0.09	"	1501	-0.58
"	1412	0.00	"	1457	0.16	"	1502	-0.23
"	1413	-0.27	"	1458	0.14	"	1503	-0.66
"	1414	1.36	"	1459	-0.43	"	1504	0.58
"	1415	-0.40	"	1460	-1.26	"	1505	0.43
"	1416	-0.72	"	1461	-1.01	"	1506	-0.72
"	1417	1.17	"	1462	-0.77	"	1507	-0.63
"	1418	0.56	"	1463	-0.81	"	1508	-0.50
"	1419	-0.21	"	1464	-0.20	"	1509	-0.03
"	1420	-0.46	"	1465	0.10	"	1510	-1.02
"	1421	-0.33	"	1466	0.00	"	1511	0.64
"	1422	-1.53	"	1467	-1.01	"	1512	0.89
"	1423	-1.00	"	1468	-0.93	"	1513	-1.24
"	1424	-0.86	"	1469	-1.05	"	1514	0.64
"	1425	0.85	"	1470	-1.08	"	1515	0.51
"	1426	1.11	"	1471	-0.41	"	1516	0.55
"	1427	-0.06	"	1472	-0.96	"	1517	0.69
4	1428	-0.80	"	1473	1.11	"	1518	1.33
"	1429	0.09	"	1474	0.24	"	1519	0.76
"	1430	0.33	"	1475	0.05	"	1520	-0.15
"	1431	1.95	"	1476	-0.02	"	1521	0.38
"	1432	1.89	"	1477	-0.13	"	1522	0.36
"	1433	0.72	"	1478	0.51	"	1523	0.46
"	1434	0.93	"	1479	-0.65	"	1524	1.41
"	1435	1.12	"	1480	-0.25	"	1525	0.78
"	1436	0.81	"	1481	0.02	"	1526	0.22
"	1437	0.43	"	1482	-0.52	"	1527	0.76
"	1438	2.19	"	1483	0.08	"	1528	-0.82
"	1439	1.34	"	1484	0.30	"	1529	-0.19
"	1440	1.61	"	1485	0.19	"	1530	0.14
"	1441	3.66	"	1486	-1.02	"	1531	-0.09
"	1442	3.09	"	1487	-0.60	"	1532	-0.81
"	1443	2.50	"	1488	0.28	"	1533	-1.02
"	1444	0.46	"	1489	-2.06	"	1534	-1.65
"	1445	2.47	"	1490	-0.83	"	1535	-1.09

NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2
4	1536	-0.93	4	1581	-0.74	8	1626	0.02
"	1537	-0.41	"	1582	-0.76	"	1627	-0.28
"	1538	-0.80	"	1583	0.24	"	1628	0.16
"	1539	-1.16	"	1584	1.36	"	1629	0.41
"	1540	-0.77	"	1585	0.74	"	1630	0.41
"	1541	-0.84	"	1586	-0.51	"	1631	0.17
"	1542	-1.51	"	1587	1.04	"	1632	-0.04
"	1543	-0.93	"	1588	0.29	"	1633	0.16
"	1544	-1.31	"	1589	0.54	"	1634	-1.03
"	1545	-1.41	"	1590	-0.57	"	1635	-0.47
"	1546	-1.01	"	1591	-1.96	"	1636	0.37
"	1547	-1.74	"	1592	-0.60	"	1637	-2.20
"	1548	-1.39	"	1593	-0.54	"	1638	-1.55
"	1549	-0.29	"	1594	-0.50	"	1639	-1.08
"	1550	-0.47	"	1595	-0.03	"	1640	-0.17
"	1551	-0.52	"	1596	-1.22	"	1641	0.63
"	1552	0.16	"	1597	-0.49	"	1642	1.55
"	1553	-0.21	"	1598	-0.57	"	1643	0.98
"	1554	-0.66	"	1599	0.39	"	1644	1.28
"	1555	-0.38	"	1600	-1.32	"	1645	1.22
"	1556	-0.52	5	1601	0.47	"	1646	-0.27
"	1557	-0.21	"	1602	0.23	"	1647	0.09
"	1558	-0.82	"	1603	0.41	"	1648	-0.81
"	1559	0.62	"	1604	0.33	"	1649	0.96
"	1560	1.08	"	1605	-0.98	"	1650	-0.31
"	1561	0.79	"	1606	-1.05	"	1651	-0.13
"	1562	1.88	"	1607	-0.69	"	1652	-0.73
"	1563	0.70	"	1608	-0.71	"	1653	0.37
"	1564	0.75	"	1609	0.76	"	1654	-0.26
"	1565	1.10	7	1610	1.56	"	1655	0.20
"	1566	2.01	"	1611	1.00	"	1656	0.53
"	1567	0.92	"	1612	1.80	"	1657	0.09
"	1568	1.50	8	1613	1.98	"	1658	0.37
"	1569	1.71	"	1614	0.72	"	1659	0.23
"	1570	1.13	"	1615	2.60	"	1660	-0.76
"	1571	1.72	"	1616	2.71	"	1661	-0.18
"	1572	1.68	"	1617	2.44	"	1662	-1.80
"	1573	0.68	"	1618	-1.72	"	1663	-1.53
"	1574	0.88	"	1619	-0.13	"	1664	-0.72
"	1575	-0.37	"	1620	-1.29	"	1665	-0.27
"	1576	-0.11	"	1621	-0.29	"	1666	-0.75
"	1577	0.42	"	1622	-0.43	"	1667	-0.47
"	1578	0.55	"	1623	-0.77	"	1668	-1.96
"	1579	0.72	"	1624	-0.30	"	1669	0.70
"	1580	-1.30	"	1625	0.05	"	1670	0.78

NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2
8	1671	0.25	10	1716	-0.01	15	1761	-0.24
"	1672	0.70	"	1717	-0.67	"	1762	0.31
"	1673	1.47	"	1718	-1.53	"	1763	1.59
"	1674	0.45	"	1719	-0.09	"	1764	0.96
"	1675	-0.21	"	1720	-1.41	"	1765	1.44
"	1676	0.29	11	1721	-1.27	"	1766	1.41
"	1677	-0.54	"	1722	-0.55	"	1767	1.96
"	1678	-0.72	"	1723	-0.86	16	1768	1.56
"	1679	-1.75	"	1724	-1.03	"	1769	1.14
9	1680	-0.70	12	1725	-0.55	"	1770	-0.47
"	1681	-0.29	"	1726	0.66	"	1771	1.44
"	1682	-0.38	"	1727	1.05	"	1772	-0.23
"	1683	0.59	"	1728	0.71	17	1773	0.51
"	1684	0.40	"	1729	1.57	"	1774	1.02
"	1685	0.66	"	1730	0.42	"	1775	0.93
"	1686	0.94	"	1731	0.46	"	1776	0.54
"	1687	1.31	"	1732	0.36	"	1777	0.95
"	1688	1.32	"	1733	0.87	"	1778	2.42
"	1689	0.53	"	1734	-1.43	"	1779	0.72
"	1690	0.19	"	1735	-1.00	"	1780	-0.21
"	1691	0.78	"	1736	-1.43	"	1781	-1.80
"	1692	0.95	"	1737	-0.13	"	1782	-1.25
"	1693	0.30	"	1738	0.67	"	1783	-0.23
"	1694	0.62	"	1739	1.41	"	1784	-0.86
"	1695	0.33	"	1740	3.27	"	1785	-1.51
"	1696	-1.44	13	1741	0.05	"	1786	-1.06
"	1697	-0.10	"	1742	-0.30	"	1787	-0.94
"	1698	-1.34	"	1743	-0.09	"	1788	-1.08
"	1699	0.06	14	1744	0.13	18	1789	-0.97
"	1700	-0.24	15	1745	-0.46	"	1790	-0.16
"	1701	-0.33	"	1746	-0.17	"	1791	-0.27
"	1702	0.15	"	1747	-0.34	"	1792	0.05
"	1703	0.19	"	1748	1.00	"	1793	0.32
"	1704	-0.05	"	1749	0.54	"	1794	0.07
"	1705	-0.85	"	1750	1.02	19	1795	0.94
10	1706	-1.97	"	1751	0.85	"	1796	0.92
"	1707	-0.10	"	1752	1.31	"	1797	0.13
"	1708	-0.90	"	1753	-0.86	"	1798	0.15
"	1709	0.18	"	1754	-0.29	"	1799	1.08
"	1710	-0.68	"	1755	-0.27	"	1800	0.27
"	1711	-1.14	"	1756	-0.91	"	1801	1.41
"	1712	-1.51	"	1757	-1.67	"	1802	0.76
"	1713	-0.63	"	1758	-2.06	"	1803	0.99
"	1714	-0.75	"	1759	-1.32	"	1804	0.12
"	1715	-0.57	"	1760	-1.14	"	1805	0.29

NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2	NO. OF TREES	YEAR	STD2
19	1806	0.65	21	1851	0.41	22	1896	-0.58
"	1807	-0.54	"	1852	-0.84	"	1897	-0.09
"	1808	-0.61	"	1853	-0.44	"	1898	-0.27
"	1809	-1.19	"	1854	-0.03	"	1899	0.42
"	1810	-0.33	"	1855	-1.30	"	1900	-0.25
"	1811	0.25	"	1856	-2.42	"	1901	-0.04
"	1812	0.30	"	1857	-0.95	"	1902	-0.08
"	1813	1.33	"	1858	0.18	"	1903	0.94
"	1814	0.62	"	1859	-0.51	"	1904	1.39
"	1815	0.15	"	1860	-1.21	"	1905	1.10
"	1816	0.39	"	1861	-0.96	"	1906	0.92
"	1817	-0.30	22	1862	-0.50	"	1907	1.46
"	1818	0.74	"	1863	-1.34	"	1908	1.59
"	1819	0.71	"	1864	-1.63	"	1909	0.28
"	1820	0.76	"	1865	-2.78	"	1910	0.21
"	1821	1.36	"	1866	-1.97	"	1911	-3.27
"	1822	0.33	"	1867	-0.96	"	1912	-0.92
"	1823	-1.14	"	1868	-0.74	"	1913	-0.31
"	1824	-0.56	"	1869	-0.04	"	1914	0.07
"	1825	0.38	"	1870	-1.05	"	1915	1.08
"	1826	-0.18	"	1871	-0.81	"	1916	1.47
"	1827	0.44	"	1872	-1.84	"	1917	0.09
"	1828	-0.03	"	1873	-0.28	"	1918	0.55
"	1829	0.50	"	1874	0.06	"	1919	-0.04
20	1830	0.11	"	1875	-0.42	"	1920	-0.75
"	1831	-0.31	"	1876	-1.10	"	1921	-0.41
"	1832	0.31	"	1877	-0.51	"	1922	0.53
"	1833	0.70	"	1878	0.68	"	1923	-0.02
"	1834	0.37	"	1879	1.25	"	1924	-0.07
"	1835	0.91	"	1880	0.05	"	1925	0.39
"	1836	1.22	"	1881	-0.10	"	1926	-0.06
"	1837	0.83	"	1882	1.00	"	1927	0.74
"	1838	0.39	"	1883	0.74	"	1928	0.40
"	1839	0.39	"	1884	0.43	"	1929	0.19
"	1840	0.71	"	1885	0.90	"	1930	0.91
21	1841	0.13	"	1886	0.84	"	1931	-1.80
"	1842	0.17	"	1887	0.49	"	1932	0.44
"	1843	-0.04	"	1888	1.41	"	1933	-0.20
"	1844	0.66	"	1889	0.56	"	1934	-2.76
"	1845	-0.52	"	1890	1.19	"	1935	-0.38
"	1846	-0.59	"	1891	1.30	"	1936	-2.33
"	1847	-1.19	"	1892	0.28	"	1937	-0.84
"	1848	-2.04	"	1893	-0.43	"	1938	-0.15
"	1849	0.09	"	1894	-0.16	"	1939	-3.07
"	1850	-0.34	"	1895	-0.05	"	1940	-0.95

NO. OF TREES	YEAR	STD2
22	1941	-0.34
"	1942	-0.06
"	1943	0.60
"	1944	0.37
"	1945	1.71
"	1946	2.27
"	1947	1.02
"	1948	-0.23
"	1949	0.23
"	1950	-0.39
"	1951	-0.55
"	1952	-0.09
"	1953	0.26
"	1954	-0.95
"	1955	0.26
"	1956	-0.99
"	1957	-0.36
"	1958	-0.24
"	1959	-1.01
"	1960	-0.48
"	1961	-2.88
"	1962	0.30
"	1963	0.17
"	1964	0.42
"	1965	2.60
"	1966	0.98
"	1967	0.63
"	1968	1.16
"	1969	1.31
"	1970	-0.02
"	1971	+0.02
21	1972	0.56
"	1973	1.14
"	1974	-1.39
"	1975	1.72
"	1976	1.35
"	1977	-1.38
"	1978	0.99
"	1979	0.33
"	1980	-0.97
20	1981	-0.91
"	1982	-0.25
"	1983	0.32
"	1984	0.88
18	1985	-3.15
18	1986	0.48
"	1987	0.27
16	1988	-1.20
"	1989	-0.59
15	1990	1.99
13	1991	