HIGHLIGHTS ON THE DENDROCHRONOLOGY OF JORDAN

KHALED AL-BASHAIREH

Overview
The geographic coordinates for Jordan are about 29º 11' N and 33º 22' N (latitude) and 34º 19' E- 39º 18' E (longitude) (Suleiman and Bakri 2011). Jordan consists mostly of three main geographic and climatic areas (from east to west): the arid desert, high mountains, and the Rift Valley of the Jordan River (Fig. 1).

A tree-ring is a layer of wood cells produced by a tree in one year. It consists of early wood and late wood layers (Stokes and Smiley 1968: 3). The basic principle in building tree-ring chronologies is cross-dating, or matching common tree-ring patterns or properties such as ring width or density among trees (Fritts 1976: 2; Towner 2002: 71; Shroder 1980: 161-162). Dendrochronology is simply defined as tree-ring dating science (Towner 2002: 68) or the study of tree-rings (Fritts 1965: 393). The Greek prefix dendron means tree, while chronology means the science that deals with time and assignments of dates for particular events. However, other authors define it as the general science of dating annual wood layers and their association to the environment (Shroder 1980: 161). Dendrochronology is one of the most accurate dating methods used by researchers and scholars to study and date past events. Because tree growths are annual and affected by variations in climate, the tree-ring dates are accurate, without statistical errors, and have a resolution of one calendar year (Dean 1978).

Importance of Dendrochronological Studies in Jordan
Jordan is mostly covered with desert and its climate is dry and hot; therefore, the most environmental problem of the country is the scarcity of water. The population of the country continues in rising, while water resources have remained the same over the past decades. Reconstructing past precipitation and drought records can help in careful planning for an adequate use of the limited water resources in Jordan. This depends on the prediction of the changes of precipitation and drought in time and place. Narrow and wide tree rings sequence is a proximate year-to-year variation in climate; therefore, they support future probability of these events (Touchan and Hughes 1999). In these circumstances, dendrochronology could help us to understand climatic changes in Jordan. In addition, Jordan has many archaeological sites in some of which wood was used for building some structures such as Qasr el-Bint in Petra. In addition, it is valuable to tree-ring date the construction of these settlements by building new master chronologies for other species and extending the current master chronology and find the source of the wood used (Fig. 2).

Dendrochronological Research in the Middle East and Jordan
Dendrochronological research has been utilized in most areas of the Middle East, including Jordan.
Although a number of dendrochronological studies were done in the Mediterranean area, dendrochronological study in Jordan is still in its initial stages (Touchan and Hughes 1999: 291-303). In the Near East, few dendrochronological studies have been performed aiming at developing paleoclimate records (Munaut 1982; Shanan et al. 1967), dating archaeological sites (Kuniholm and Striker 1987) and examining the cycle of cambial activity in a given tree species in order to determine which species exhibit annual growth ring development (Liphschitz et al. 1986).

The first actual dendrochronological work in Jordan began in 1995 by sampling trees from southern Jordan in order to create a long tree-ring chronology and apply this chronology to develop the first dendroclimatic precipitation record in the Middle East for southern Jordan (Touchan et al. 1999: 50). The sampled tree-ring sites were Dana Reserve in the Tafilat region, and Tor-al Iraq in the Petra region. These two sites are part of the highlands of southern Jordan where elevation ranges between 1100 and 1400 meters above sea level (masl) (Fig. 1). Touchan and Hughes (1999) expanded their previous work by sampling trees from three locations in northwestern Jordan (Bani Kenana region, Wadi al-Muntamera and Heraj al-Ourthan, Dibeen, Ajloun region) and one location on the Carmel Mountain in western Palestine (see Fig. 1). Elevations of the sampled sites ranged between 400 (Bani Kenana) and 1300 (Dibeen) masl.

a- Tree Species Studied

The dominant trees at the sampled sites are as follows: deciduous forest (*Quercus aegilops*) in Bani Kenana to coniferous forest (*Pinus halepensis*) in Dibeen, *Juniperus phoenicea* in southern Jordan, and *Pinus halepensis* at Carmel Mountain. Dibeen sites consist of a pure stand of *Pinus halepensis* and a mixed stand of *Pinus halepensis* and *Quercus cocciifera*. The site in southern Jordan varies from pure stands of *Juniperus Phoenicea* to areas mixed with *Pistacia atlantica* and *Quercus calliprinos*. The overstory at Carmel Mountain varies from pure stands of *Pinus halepensis* to areas mixed with *Quercus calliprinos* and *Pistacia palestina*.

Three kinds of trees were sampled and studied:

1) *Juniperus poenicea* (Phoenicean Juniper: Fig. 3): Seventeen cross-sections of *Juniper poenicea* trees were sampled from Dana Reserve and Tor - al Iraq (Table 1). This tree grows up to 6m in semiarid climates (Rehner 1968: 63). In cross-section the sapwood is yellowish and the heartwood is dark brown, and its density is about 500 kg/m³. It is difficult to use it for dating purposes because only a few old stands exist extremely isolated and varied (Schweingruber 1993: 74-77). However, Liphschitz (1986) reported that one chronology from the Sinai reached back to 1102 A.D., and contains floating chronology from the time period between the 4th and 1st century B.C.
### Table 1: Tree-ring chronology sites, listed from north to south (adapted from Touchan and Hughes 1999).

<table>
<thead>
<tr>
<th>Chronology</th>
<th>Species</th>
<th>Time span</th>
<th>Years</th>
<th>N. Trees</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carmel Mountain</td>
<td><em>Pinus halepensis</em></td>
<td>1915-1996</td>
<td>82</td>
<td>8</td>
<td>9 0</td>
</tr>
<tr>
<td>Bani Kenana</td>
<td><em>Quercus aegilops</em></td>
<td>1906-1995</td>
<td>90</td>
<td>12</td>
<td>0 12</td>
</tr>
<tr>
<td>Dibeen</td>
<td><em>Pinus halepensis</em></td>
<td>1920-1994</td>
<td>75</td>
<td>14</td>
<td>14 0</td>
</tr>
<tr>
<td>Southern Jordan</td>
<td><em>Juniperus poenicea</em></td>
<td>1469-1995</td>
<td>527</td>
<td>17</td>
<td>0 17</td>
</tr>
</tbody>
</table>

2) *Pinus halepensis* (Aleppo Pine: Fig. 4): Nine cores of *Pinus halepensis* were sampled from Carmel Mountain and fourteen cores of the same species were sampled from Dibeen (Table 1). The tree has a maximum stem diameter of 0.9 m and may grow to 20 m tall in dunes as well as on rocks (More and White 2002). It needs at
least 300 mm of precipitation yearly and the most resistant species to drought in this region. Sapwood in this species is narrow and white in color while the heartwood is yellow. It’s about 650 kg/m³ in density and is very sensitive to fire. The longest chronology built from this species goes back to 1803 A.D. in the Mediterranean region (Schweingruber 1993: 123).

3) *Quercus aegilops*: Twelve cross-sections of *Quercus aegilops* were used from Bani Kenana (Fig. 5, Table 1). This tree, which is spread throughout Northern Jordan, is a turkey oak, *Quercus cerris*. The species name is Latin for “the fringe” and refers to the hairy cups of the acorns. It grows up to 30 - 35 m high with a trunk of 1.3 m in diameter (Schuler 1978: 62).

**b- Results of the Previous Research**

The main results of the previous two studies were: 1) a 396 year (AD 1600 to 1995) reconstruction of October-May precipitation from *Juniperus phoenicia* chronology for southern Jordan; 2) one annual tree-ring width chronology was created for north Jordan; 3) there was a good correlation between tree-ring sites in northern Jordan while the northern and southern sites did not show any correlation; 4) the longest reconstructed drought (<217.4 mm), defined as consecutive years below a threshold of 80% of the 1946–1995 mean observed October–May precipitation, was 4 years, compared with 3 years for the 1946-95 instrumental data; and 5) there was a strong relationship between growth and precipitation.

**Problems and Improvement of the Previous Work**

Dendrochronology may appear to be an area of simple study, but actually it faces many challenges. In Jordan, dendrochronologists have faced some difficulties. First of all, the Middle East countries surrounding Jordan do not have climatic reconstructions of precipitation and it was not possible to use the available climate reconstructions of the Mediterranean region (Meko 1985; Stockton 1985; Chbouki 1992) because of the large distance and climatic variability. Therefore, it was necessary to build a new chronology for Jordan.

Touchan *et al.* (2005) represented the first large-scale systematic dendroclimatic sampling focused on developing precipitation (May – August) chronologies from different species in the eastern Mediterranean region (Turkey, Syria, Lebanon, and Greece). Another problem that dendrochronologists faced in Jordan was the difference in climate between southern and northern parts of Jordan. Although the eastern and southern parts of Jordan are deserts, small areas of forests-like exist in the north and the highlands of the south. Furthermore, calibrated data to high quality instrumental climatic records was very limited because they go back to the 1940s and 1950s only and contain little information on climate variability over longer periods.

In the future, more samples are needed to improve the recent chronologies and to verify previous results, while in south Jordan, more samples would increase the length of the present chronology and give more accuracy in cross-dating. It is necessary to understand the regional climate and its past variations by collecting and studying tree-ring samples from the neighboring countries and correlate them to samples from Jordan. It is also possible to
improve recent and future studies and chronologies by comparing them to other indirect evidence of climate variability.

Recent Work

Recently, a project entitled "the Southern Levant Dendrochronology Project" was launched. It is a laboratory subproject that started in 2007 to date timbers of native species from sites in the southern Levant and build up a database for them. The first phase of this project has sampled *Pinus halepensis* trees growing in a modern forest in the southern Levant in order to investigate their response to climate and to examine variability in the tree-ring record. A second aim of the project is to investigate several shipwreck sites and to date them as accurately and precisely as possible (http://dendro.cornell.edu/projects/aegean.php), accessed on 13-7-2013.

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