Turning Over a New Leaf

An Assessment of the Dendrochronological Potential of Three Indigenous Ancient Egyptian Trees

by

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STATEMENT BY THE AUTHOR

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APPROVAL BY RESEARCH COMMITTEE

As members of the Research Committee, we recommend that this thesis be accepted as fulfilling the research requirement for the degree of Master of Science.

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FICUS SYCOMORUS

Wood Anatomy

Literature Review

TAMARIX SPP.

Wood Anatomy

Literature Review

ACACIA SPP.

Wood Anatomy

Literature Review

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Often conceived of as a sterile, sun-scorched desert, the perceived paucity of vegetation in Egypt belies a robust and ancient history of wood use. The study of native wood species in ancient Egypt has received scant attention outside of a narrow art historical lens, and stands to benefit greatly from the application of tree-ring research. If possible, the development of a dendrochronology for ancient Egypt using native tree species has the potential to finally resolve perennial issues with the historical chronology of ancient Egypt and to explore the societal impact of environment and wood-use behaviors. To this end, the aim of this thesis is to fully evince the critical need for tree-ring studies in Egypt, elucidate and address the criteria necessary for performing dendrochronology in an Egyptian context, and to provide a relevant literature review of research on the three dominant indigenous trees used in ancient Egypt (Ficus sycomorus, Tamarix spp. and Acacia spp.) in order to assess their potential viability for dendrochronological analysis. Results of these preliminary examinations dismiss the datability of Ficus sycomorus, and tentatively confirm the potential to date Tamarix spp. and Acacia spp. assuming conditions for tree growth and archaeological sampling prove extremely favorable.
Chapter I. Introduction and Background

In many ways, the question of a dendrochronology composed of native species in Egypt was dismissed before it was even raised, for what application could tree-ring science have in an ostensibly tree-less land? While often conceived of as a sterile, sun-scorched desert, the perceived paucity of vegetation in ancient Egypt belies a robust history of wood use that probably favored, by volume, locally available materials over expensive imports. The fallacy concerning Egypt’s dearth of timber was propagated not only by the reality of the environment (90% of the land of Egypt is desert), but also by the assertions of early Egyptologists who exuberantly expounded the shortcoming of the country’s native resources.\(^1\) Traditional thought dictated that although Egypt was better limbered in antiquity\(^2\), the native wood was of a “very unserviceable nature.”\(^3\) Compared to the covetable gymnosperms of, presumably, the Levant, the knotty, coarse sycamore and stunted tamarisk\(^4\) of Egypt were dismissed as inferior products that the ancients would never have deigned to use but for a pressing necessity. The hyperbolic notions established by these nascent writers prevailed for more than a century, as scholarly attention given to the material study of wood in ancient Egypt was limited and myopic, favoring imported species (i.e., *Cedrus libani*). A great number of wooden artifacts in museums across the globe have never been evaluated to identify even the type of wood\(^5\), let alone species, or else have been improperly identified, leaving large gaps in our knowledge of native Egyptian wood

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1 e.g.: Wilkinson 1837; Erman 1894
2 See Leospo 1988; El-Ghani 1997; Zahran and Willis 2009; Gale et al. 2000
3 Erman 1894:451
4 Acacia, perhaps because of its misidentification (Loret 1892) in Egyptian texts as *ash* wood (likely *Abies cilicica* [Lucas and Harris 1962]), inferences drawn from textual evidence documenting the importation of acacia from Nubia (Breasted 1906; Blakemore 2006; Gale et al. 2000), or an alleged absence of wild acacia in 20\(^{th}\) century Egypt (Petrie 1920), was regarded by some as an import, being all but extinct in Egypt as early as the Old Kingdom (Erman 1894:451). Pollen analyses, plant remains, and the wealth of artifacts, textual and art historical evidence recovered from or referencing the pharaonic period, however, would seem to indicate that acacia was in fact prevalent in ancient Egypt (Zahran and Willis 2009, Gale et al. 2000; Lucas and Harris 1962; Kuniholm 1997).
5 Kuniholm et al. 2014
exploitation. The pejorative lens through which native wood was viewed by “modern” scholarship—an opinion certainly not shared by the ancient Egyptians, whose cosmology and art demonstrates a great reverence for their native ecology (Figure 1)—has colored the way we understand Egyptian wood-use behaviors.

Figure 1: Deceased kneeling to imbibe from spring at base of date palm; Tomb of Pashedu, 19th Dynasty c. 1295-1186 BC, Deir el-Medina (R. Caroli)

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Even a cursory look at a representative sampling of wooden artifacts from museums around the world (Table 1) indicates that native wood was exploited to a far greater extent than is appreciated and was certainly the primary, if not only, resource available to the archaeologically underrepresented non-elite population of ancient Egypt. A concerted and comprehensive dendroarchaeological exploration of native Egyptian wood has the potential to yield new data pertaining to a broad range of ecological, behavioral, climatological, and chronological questions. Especially in terms of chronology, there is a pressing need to capitalize on dendrochronology as a previously untapped avenue of investigation to address problems and questions that only the study of tree rings, when successful, may resolve.

| Wood Types        | Nibbi (1981)
|                  | Louvre
|                  | Grosser (1992)
|                  | Munich, and others
|                  | Davies (1995)
<table>
<thead>
<tr>
<th></th>
<th>British Museum</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ficus sycomorus</em></td>
<td>32</td>
</tr>
<tr>
<td><em>Tamarix sp.</em></td>
<td>&gt;100</td>
</tr>
<tr>
<td><em>Acacia sp.</em></td>
<td>35</td>
</tr>
<tr>
<td><em>Cedrus sp.</em></td>
<td>5</td>
</tr>
<tr>
<td><em>Juniperus sp.</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Pinus sp.</em></td>
<td>9</td>
</tr>
<tr>
<td><em>Cupressus sp.</em></td>
<td>–</td>
</tr>
</tbody>
</table>

Table 1: Sampling of tree species used in ancient Egyptian artifacts from world museums (After Cichocki et al. 2004 Table 4.2)

Across the world, and in places never before thought suitable for dendrochronological investigations, gaps in contemporary and archaeological knowledge are being filled by the data

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7 Lucas and Harris 1962; Kuniholm 1997
tree-ring studies can provide.\(^8\) With investigations undertaken and ongoing in the Mediterranean, the Near East, and in North and East Africa, Egypt represents a glaring lacuna in the growing patchwork of a global tree-ring database. As the field of dendrochronology increasingly expands into uncharted grounds and avenues of research once thought impossible, the question is begged, why not Egypt? A confluence of factors may account for Egypt’s notable omission, including a skewed perception of the ancient environment, a traditional focus on the elite art historical and mortuary record, a chronometric overreliance on textual data, a disinclination to embrace independent methods of scientific inquiry, the preemptive dismissal of the dendrochronological viability of native species and restrictions against invasive sampling of archaeological material.

The result is that, although repeatedly proposed,\(^9\) dendrochronology has not yet been applied to Egypt in any effectual way. The purviews of the few forays that have taken place in the last decade have been exclusively limited to imported coniferous species, for which the possibility of crossdating has been well established. Virtually no attention has been given to the native tree species of Egypt from which we must draw, if dendrochronology is possible, to obtain greater chronological clarity and address questions of local climate, hydrology, ecology and wood-use behavior. More than any other factor, inertial efforts weigh against the implementation of dendrochronology in Egypt; because it has not yet been done, there is a tacit assumption that it cannot be done.\(^{10}\) The aim of this thesis is thus to fully evince the critical need for tree-ring studies in Egypt, elucidate and address the criteria necessary for performing dendrochronology in an Egyptian context, and finally to provide a relevant literature review of research on the three most prevalent indigenous tree types from pharaonic Egypt’s archaeological record (\textit{Ficus}

\(^8\) e.g., Nicolini et al. 2010; Trouet et al. 2012
\(^{10}\) e.g., Kuniholm et al. 2014
Sycomorus, Tamarix spp. and Acacia spp.) in order to assess their potential viability for dendrochronological analysis.

TREES IN ANCIENT EGYPT

“It has become difficult to ignore the possibility that major segments of ancient Egyptian history may be unintelligible without recourse to an ecological perspective”


Ancient Egypt was a land governed by predictable environmental cycles. Recurrent astronomical observations and the annual inundation of the Nile dictated the civil and religious calendars, provided the basis for the ancient Egyptian cosmology, and regulated everyday life. Egypt’s three seasons, akhet (inundation), peret (growth/winter) and shemu (harvest/summer) were predicated upon the Nile’s annual periodicity, and the notions of a regular rise and fall, of death and rebirth (or indeed, dormancy and growth) permeated their worldview. The Egyptians understood most aspects of their environment to be regulated by these predictable and well-documented cycles; the question is whether the same response to the cyclical fluctuations of the environment was similarly recorded in the growth rings of indigenous trees.

Environment

The modern (perceived) sterility of the land of Egypt, while overestimated, is not particularly unfounded (Figure 3). Located in the northeastern-most portion of the African continent, the entire country is bounded by the great desert belt that subsumes North Africa and
Arabia. Characterized by a hot and nearly rainless climate, 90% of Egypt is barren desert, termed the Red Land or, with appropriate coincidence, *dsrt* by the ancient Egyptians.\(^{11}\)

Average yearly rainfall across the modern state of Egypt amounts to only 10 mm, although zones of higher precipitation, such as the northern and mountainous coastal areas, will yield closer to 200 mm per year.\(^{12}\) Climatically the country is divided into two types of provinces: hyper arid and arid. The former experiences exceptionally hot summers and mild winters with an average annual winter rainfall of 30 mm, whereas the latter is typified by hot summers and increased

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\(^{11}\) Shaw 2000
\(^{12}\) Zahran and Willis 2009; El-Ghani 1998, 2003
winter rainfall, in the order of 200 mm.\textsuperscript{13} Although rainfall is low, when it does occur, the desert explodes with reinvigorated life as ephemeral wadis (dry river beds) bloom with perennial and annual plants. In antiquity, precipitation was relatively more significant, with geomorphological and archaeological studies suggesting that the area of Egypt experienced multiple intervals of drought and punctuated rainy periods over the millennia.\textsuperscript{14} One such rainy period occurred between 8,000 and 4,000 BC, and had dwindled by 3,000 BC, although surface water was still present at that time in the now hyperarid Western Desert.\textsuperscript{15} Throughout Egypt’s history, the most reliable and voluminous source of water was always the Nile River that bisected the land and brought fecundity to an otherwise inhospitable environment. With rainfall rare and irregular in all but the northernmost region of the Delta, for thousands of years (until the ultimate damming of the river at Aswan during the 20\textsuperscript{th} century), life in Egypt depended on the Nile’s annual floods. Each inundation period flushed away accumulated salts and deposited fresh silt, ensuring a stable swath of eminently arable and verdant land.

Seldom considered a forested land, pollen analyses undertaken across the country indicate that, until at least the Early Dynastic Period (about 3,500 BC), the Nile Valley supported evergreen forests of fig, jujube, acacia, tamarisk and other species including doum and date palm.\textsuperscript{16} For this reason, Egypt probably never found itself short of timber suitable for the majority of construction purposes, in spite of the greater part of the surface area being desert.\textsuperscript{17} The disappearance of these heavily vegetated zones is attributed by some\textsuperscript{18} to a period of massive deforestation occurring during the Old Kingdom for fuel and in advance of expanding

\textsuperscript{13} El-Ghani 1998:298
\textsuperscript{14} Murray 1951; Abu Al-Izz 1971; Ayyad and Ghobbour 1986; Zahran and Willis 2009; El-Ghani 1998, 2003
\textsuperscript{15} Murray 1951; El-Ghani 1998, Hill 2007
\textsuperscript{16} Butzer 1959; Hughes 1992; Zahran and Willis 2009; Hepper 1990
\textsuperscript{17} Mark 2012
\textsuperscript{18} Hughes 1992; Lehner et al. 1999
cultivation and animal grazing. Depictions in tomb paintings of felling trees and agricultural clearing superficially seem to support this hypothesis (Figure 3); however, most comprehensive ecological studies of Egypt beyond agriculture and gardens are limited to the pre-pharaonic period, rendering the timing, cause and veracity of a possible deforestation event or events as yet speculative. As is often the case in the study of ancient Egypt, questions of ecology during the pharaonic period instead rely heavily on interpretations of the abundant textual record, frequently without the benefit of independent scientific verification. Although timber was a highly demanded and relatively non-renewable resource, given the increasing aridity of Egypt's climate, a significant bulwark against critical deforestation was manifest in the exceptional cultural appreciation and value with which the ancient Egyptians imbued their sacred native trees.

Figure 3: Ancient Egyptian wood felling scene in tomb of Nefer, 5th Dynasty c. 2498–2345 BC; Saqqara (R. Caroli)

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19 e.g., Zahran and Willis 2009
20 Hughes 1992; Shaw 2000
Culture

Even the most casual examination of Egyptian art imparts a profound reverence for trees, the exploitation of which was characterized by a marked conscientiousness. According to Hughes, “the ecological attitudes and practices of the Egyptians were rooted in a world view that affirmed the sacred values of all natures and of land in particular.” A beacon of life in the arid desert, trees denoted the presence of water and provided rare shade, sustenance and protection, leaving little wonder as to why they were so strongly associated with the divine. Egyptian cosmology held that, at the beginning of the world, the sacred ished tree (tree of life) unfolded itself upon the appearance of the sun-god, and that on the leaves the god set down the names and years of the kings of Egypt to serve their annals. Divine trees were a frequent motif in mortuary artwork, especially during the New Kingdom, with the deceased bowing low before them or drinking from a spring or cup at its base (Figure 4).

Figure 2: Deceased accepting water from the goddess in a sycamore tree; Tomb of Sennedjem 19th Dynasty c. 1295-1186 BC; Deir el-Medina (R. Caroli)

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21 Hughes 1992:12
22 Keel 1937:79
Art imitated life, as real trees were planted in cemeteries with the expectation that the residing tree-deities, usually in the form of a goddess of heaven, would pour libations for the dead. The principal goddesses Hathor and Isis both embodied sycamore trees, and their portrayal in artwork as a tree with breasts from which pharaoh received milk provides a visceral testament to the life-giving role of trees in Egyptian society (Figure 5). Intertwined with the conception of trees were beliefs regarding “fertility, rejuvenation, resurrection, creation and divined protection.”

Figure 5: Goddess of the Sycamore nursing pharaoh Thutmose III; 18th Dynasty c. 1543–1292 BC; KV 34 (R. Caroli)

23 Keel 1937:78
24 Wilkinson 2003; see Appendix G
25 Pepler-Harcombe 2011:21
Cultivation of trees was both an art and a skill, and the planting of trees was considered a “good work” that aided one’s soul on its progress toward justification in the afterlife. Tomb paintings and models demonstrate that officials and wealthy citizens kept gardens of trees (e.g. the Meket-Re models; see Figure 6); they were a ubiquitous feature of temples and pharaohs retained plantations of valuable species for royal use.

As early as the Old Kingdom, the state recognized the value of Egypt’s native timber, offering special tax exemptions for trees and prohibiting the felling of sycamores except by special decree by the vizier. Innovative methods of woodworking arose in Egypt out of necessity, with the gnarled timbers of acacia shaped into beams and planks, and deftly assembled by means of joints and lashing into eminently seaworthy vessels: Egypt’s most intensive use of wood. When Hatshepsut (c. 1479-1458 BC) realized her divinely inspired task of quarrying two massive obelisks (weighing in the order of 323 tons), it was likely a colossal barge of sycamore that transported her monoliths to Karnak Temple. An innately riverine country, boats were of particular importance in ancient Egypt and well-served by the native light-weight and water-repellent wood; however, indigenous species were also broadly applied in the construction of coffins, boxes, furniture, bows, arrows, tools, architectural elements, toys, models and various other crafts.

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26 Hughes 1992:19
27 Winlock 1995
28 Keel 1937; Hughes 1992
29 From *The Instruction of Rekhmire*: “It is he (i.e. the vizier) who dispatches to cut down trees according to the decision in the king's house” (Breasted 1906 v2:697).
30 Erman 1894; Creasman 2014b
31 Habachi 1977
32 Lucas and Harris 1962; Gale et al. 2000; Cartwright and Middleton 2008; Cartwright and Taylor 2008; Pepler-Harcombe 2011
Despite perceptions, the environment of ancient Egypt supported a relatively abundant growth of certain native tree species, the importance of which to the life and ecology of the ancient Egyptians is underscored by their prevalence in the art historical and archaeological record. Greater investment is needed in the scientific investigation of the culture and environment of ancient Egypt; the study of native species is a relevant and worthy endeavor that could aid in the reconstruction of Nile flow, flooding, droughts, pestilence and wood-use behaviors of the ancient Egyptians. Whether the idiosyncrasies of the Egyptian environment impart a reconstructable signal in the formation of the native trees’ growth rings is a question
that may only be answered through the rigorous sampling and physical examination of native
tree anatomy. In advance of such vetting, the utility of dendrochronology to provide new and
much needed insight into one problematic facet of the known art historical record, namely the
construction of the ancient Egyptian chronology, is expounded as an impetus for further study.
Chapter II. The Need and Context for Tree-Ring Research in Egypt

A concerted effort towards establishing a comprehensive program of dendrochronological study in Egypt represents no small feat. Tens-of-thousands of samples often contribute to the creation of a master chronology (by which absolute dating is achieved), necessitating countless hours of acquisition, preparation, comparison and analysis. Indeed, for a culture with antiquity as significant as ancient Egypt, it would not be unreasonable to expect to draw upon hundreds-of-thousands of samples. In order to justify the attempt, a vital need for such an endeavor must be clearly educed, as well as the relative probability for success. Egypt has already an apparently secure chronology relative to other cultures of similar (or more recent) antiquity, based on the appreciable volume of its extant archaeology and robust written record. The following section will relay the deficiencies inherent to the current chronology and demonstrate the unique capacity of dendrochronology to address the specific obstacles presented. Although resolution of the ancient Egyptian chronology represents a crucial contribution, other areas of research that could greatly benefit from the implementation of tree-ring studies in Egyptology are also elaborated. Lastly, the minimal criteria requisite for performing dendrochronological studies are identified and the capacity of Egypt to satisfy the parameters is evaluated.

CHRONOLOGY

By the 1940s, the historical chronology of ancient Egypt was believed already to have achieved a level of precision so refined that it was utilized by Willard F. Libby to evaluate the success of his newly developed method of radiocarbon dating.\textsuperscript{33} The radiocarbon dates determined for a sample of acacia from the pyramid of Djoser (c. 2800 BC) correlated well

\textsuperscript{33} Libby 1960
enough with the established historical dates for the pyramid to prove the soundness of Libby’s theory. In the decades since, $^{14}$C dating has become only more refined, while increasingly the shortcomings and pitfalls of Egypt’s historical chronology have been evinced. Critical analyses of the traditional historical dating techniques (e.g., synchronisms, astronomical phenomena) have called into question their validity and error margin, demonstrating that perhaps “the ‘precision’ assumed by present-day scholarship is an illusion.”

The extraordinary bounty of literary evidence from ancient Egypt is both a gift and a curse. Although the detailed lists, records, and letters have allowed the creation of an impressive historical chronology, the overreliance on incomplete, erroneous and subjective material has produced an inherently flawed product that is too often accepted as “correct enough” without independent verification. Because of the perceived precision of the historical chronology, it became de rigueur among Egyptologists to eschew independent chronometric techniques, which have proved valuable for the dating of areas lacking the corpus of written material that exists for ancient Egypt. Rather than providing an unbiased check for the historical record, the results of absolute dating techniques, such as radiocarbon, were frequently cherry picked to support various chronological interpretations of the historical record, and discounted when the data were contradictory. In recent years, radiocarbon dating has been more broadly accepted in Egypt, and has contributed to the creation of competing chronologies. Far from finally resolving the breach between absolute scientific techniques and historical dead reckoning,

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34 see James et al. 1991; Goldberg 1995; Hagens 1996; Bietak 2007; Kitchen 2013; Manning 2006; Shortland 2013; Creasman 2014a, 2013
35 Ward 1992:62
36 Manning 2006
37 E.g., Kitchen 2002 (11): “Science cannot solve the intricate problems of detailed Egyptian successions and cross-links with neighboring Near East—texts alone can do that.”
38 Manning 2006
39 Manning 2006
40 Bietak and Hofmayer 2007; Ramsey et al. 2010; Manning 2006
however, radiocarbon investigations have instead underscored the need to reconsider the chronology of Egypt and the methods by which we interpret ancient Egyptian dates. The historical (low) chronology and radiocarbon-based (high) chronology for ancient Egypt are utterly irreconcilable\textsuperscript{41}, and each has its inherent weaknesses. Currently these two chronologies are both broadly, but independently accepted standards for Egypt, each with its proponents and detractors, although additional works have been published arguing for differing interpretations entirely.\textsuperscript{42} Even within the accepted high and low chronologies, any given publication may cite a different age, suited to the author’s purposes or convenience, extracted from the range of dates inherent in either chronology.

Of further note is that any error accepted in the dating of ancient Egypt bears ramifications beyond the geographic borders of the country. The chronology of Egypt functions as the backbone for the construction and interpretation of time in the second and third millennia BC throughout the Aegean and the Near East.\textsuperscript{43} As a consequence, a discrepancy in the Egyptian timeline may ripple across the dependent and synchronized Mediterranean chronologies, compounding in magnitude and scope. A survey of the methods of dating and their criticisms elucidates the inability of any current relative or absolute dating method to provide a chronology resolved with such clarity as to improve our understanding of time in ancient Egypt.

\textit{Historical Chronology}

The creation of the historical chronology relies largely on the process of “dead-

\textsuperscript{41} Bietak and Hoflmayer 2007: 13
\textsuperscript{42} e.g., Rohl 1995
\textsuperscript{43} Renfrew 1996
reckoning,” the method of beginning with a fixed point in history (presently the foundation of the Twenty-Sixth Dynasty established after the sack of Thebes in 664 BC) and counting back by known regnal years, the most common historical method of keeping time in ancient Egypt. Fixed points are drawn from theoretically well-dated interregional events and synchronisms between Egypt and the Near East, but are all concentrated in the late first millennium BC and early first millennium AD. From established points, the backwards counting is made possible, such as it is, by the records of Egyptian King Lists. Supplemental evidence is gleaned from archaeological data (e.g., ceramics, stratigraphy and super-position) to reinforce relative sequences, and from calculations based on astronomical phenomena (solar, lunar and astral). The result is a “complex web of interpretable interlocking, often contradictory data, variable by period, but featuring an inevitable decrease in precision with increasing age.”

King Lists

The foundation for the historically derived chronology strongly rests on the Egyptian King Lists (Figure 7): official chronological annals detailing the regnal years of pharaohs. Although a few instances of these King Lists survive (none matching one another precisely), the bulk of our knowledge is derived from the works of the Egyptian priest Manetho. Among his many writings was the Aegyptiaca, in which Manetho reconstructed the regnal years of the pharaohs up until the conquest of Alexander III of Macedon. This work was dedicated to Ptolemy II (c. 285-246 BC) under whom Manetho likely served, approximately dating the production of the Aegyptiaca to the early third century BC. As a priest, Manetho would have had

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44 Schneider 2006
45 Shortland 2013
46 Shortland 2013:27
access to sources in temple libraries long since lost and an extensive oral and literary knowledge of the history and mythology of Egypt.

Figure 7: King List in Temple of Seti I; 19th Dynasty c. 1290-1279, Abydos (R. Caroli)

Despite constituting the primary source from which the entire historic chronology of Egypt is built, no copy of Manetho’s *Aegyptiaca* survives today. Rather, all that remains are partial copies, cited or quoted in works of later authors, and an epitome (not likely compiled during Manetho’s time) that is likewise only partially preserved in later writings. Several hundred years later, in the first century AD, the writer Josephus preserved several extracts from Manetho’s text, drawing both directly and indirectly from the *Aegyptiaca*. Subsequent authors render transcriptions, including Sextus Julius Africanus, who is supposed to provide a relatively accurate account of Manetho’s work in AD 220, Eusebius of Caeserea, writing in AD 326 who notably amended the original text and finally George the Monk, known as Syncellus, who in AD
800 sought to use Manetho’s work to establish a date for the birth of Christ.\textsuperscript{47} Between the remnant copies there are mistakes and discrepancies, including errors in names, incorrect ordering, missing kings and differing reign lengths.\textsuperscript{48} In all cases, the original work was adopted and adapted to further the political and/or religious agenda of the author, subtracting a certain level of credibility as objective sources.

Manetho himself was an Egyptian priest writing in Greek and surely had his own agenda (i.e. tracing the Greek rulers’ line to the founders of Egypt), reflected in the amplification or extension of the reigns of certain pharaohs and minimization of the reigns of other pharaohs.\textsuperscript{49} Writing in the third century BC, Manetho was also by no means a contemporary source; the history of Egypt had already spanned many millennia by the time of his compendium and was at the time ruled by Macedonian Greeks. He was consequently limited by the sources available to him, and their inherent bias and inaccuracies. The level of detail varies throughout the text, for some dynasties there is only a record of the number of kings and their regnal years, for others a more comprehensive record of relationships, reign lengths and significant events is included.\textsuperscript{50}

The ancient Egyptians, as with most cultures, had a predilection for rewriting their own history, omitting inconvenient pharaohs or simplifying successions and co-regencies. They were certainly not above error in transcription, lacunae in historical knowledge, and confusion or misinterpretation of past events (intentional or otherwise).

Supplementing Manetho’s king list are the partially preserved examples found on the walls of temples and chapels, or associated with archaeological sites. Five key sources exist: The Palermo Stone (c. 2400 BC), the Hall of Records in the Temple of Amun at Karnak (c. 1450

\textsuperscript{47} Shortland 2013:20
\textsuperscript{48} Shortland 2013:20
\textsuperscript{49} Shortland 2013
\textsuperscript{50} Shortland 2013:20
BC), the Temple of Abydos (c. 1250 BC), the Turin Royal Canon (c. 1250 BC), and the tomb chapel of Tjunuroy (c. 1279-1213 BC). These original materials are probably among the sources from which Manetho drew, and are closer in date to their recorded events than Manetho’s work, but were in many cases still recorded centuries or millennia later themselves. Some list the kings’ names in order, other provide reign lengths and occasional details. In general they are similar to Manetho, although occasionally kings are listed who are missing in Manetho’s list. These resources are invaluable, but they represent a highly simplified snapshot of what was a decidedly complex picture involving co-regencies, periods of instability with multiple and foreign rulers over parts of Egypt, and other circumstances resulting in non-linear rules and transitions. Other evidence includes genealogical lists of priests or viziers, the dates of burial of sacred Apis bulls, and family histories that can be linked to royal reigns, but all are problematic in a variety of ways.51

Synchronisms

It has long been believed that “Egyptian data alone are not sufficient to produce a sound and detailed chronology for pharaonic Egypt,” and must necessarily be supplemented by corresponding data from Near-Eastern contemporaries, and vice versa.52 To provide relative pins to anchor events and periods, scholars draw from synchronisms with neighboring regions, as when an object of known date from a particular culture is discovered within a reliably datable context for some other culture.53 When such connections can be established, these synchronisms may corroborate and clarify the Egyptian record. Data from Assyria are the most prevalent, including reconstructed king lists, in the same vein as the Egyptian king lists, and eponym lists,

51 Shortland 2013
52 Kitchen 2013:1
53 Shortland 2013:21
which are derived from the early second millennium-early first millennium BC Assyrian practice of assigning each year the name of the serving magistrate for that period. These names can then be linked with contemporary events of international significance, which in turn can be tied to the Egyptian chronology. Although the Assyrian records are perhaps the most prominent, information is likewise drawn from other sources, including Babylonian and Hittite evidence. The most important of these synchronisms for dynastic Egypt are the Amarna letters: official exchanges between the rulers of Egypt and neighboring nations, which can fix the contemporaneous reign of identified individuals. Unfortunately, established dates such as these are entirely limited to the comparatively well documented late first millennium BC, and relationships become increasingly more tenuous with greater age. Prior to the 600s BC, no synchronisms with the Near East can provide the level of precision needed to correct or amend chronologies that have already achieved such a level of specificity as provided by the historic data.

Astronomical Phenomena

It has been hitherto accepted in the Egyptological community that the only way to pin the historical chronology to absolute time in the second and third millennia BC is by linking it to rare astronomical phenomena. These can be generally categorized under three types of events: solar, lunar and astral. In rare cases, important and exceptional astronomical events were recorded by the ancient Egyptians. Supposing the account of such an event can be reliably associated with the reign of a particular pharaoh, calculations back from the earliest dated

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54 Shortland 2013:21  
55 Kitchen 2013  
56 Shortland 2013:23  
57 Kitchen 2013; Shortland 2013
occurrence of said event should provide an absolute date for the ancient record. However, the process for all methods of dating astronomical phenomena is rife with uncertainty, much of which cannot be resolved by the scant ancient evidence available (e.g. the location within Egypt where an observation was made is rarely confirmed, which is an issue as latitudinal position can impact interpretation).

Solar Eclipses

In any given year, two full eclipses of the sun are visible from the small patch of the earth’s surface that happens to be passing directly under the moon’s umbra. Consequently a total solar eclipse occurs at certain coordinates on the Earth’s surface only once every few decades, the precise day of which can be calculated. Should a solar eclipse have been recorded in ancient Egypt, it is theoretically possible to determine the exact date of that eclipse. Any known data contemporary to the record of that event would, as a consequence, be absolutely dated. Unfortunately, only a few mentions of solar eclipses appear in ancient records, all too recent to provide new insight (763 BC and 610 BC). No eclipses are known to have been recorded in any earlier period of Egypt’s history.

Lunar Observations

The Egyptian religious calendar revolved around the lunar cycle. The start of each 30-day month began with the final disappearance of the last part of the moon’s crescent. When the moon was invisible just before sunrise, it marked the first day of the lunar month. Double-dated documents (records with Egyptian date in the [solar] civil calendar and in religious [lunar]

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58 Wells 2002; Shortland 2013
59 Espenak and Meeus 2009
60 Shortland 2013:25
calendar) provide means for calculation, from which many researchers purport to be able to
derive the absolute days of the recorded lunar calendar.\textsuperscript{61} The process is, however, highly
subjective. Using the same event and formula of computation, each published investigator came
up with a different date, and in one case, a radically different dynasty.\textsuperscript{62} With the possibility of
multiple calendrical matches for one distinct event, the determination of any date would be of
low statistical significance. According to Wells,\textsuperscript{63} a statistically valid determination of an
absolute date by this method, assuming perfectly observed, error-free data, would require
sequential knowledge of between 250-300 precisely spaced month lengths, an impossibility
given the paucity and fragmentary nature of the existing records. Moreover, the chance of error-
free observation is highly limited. Experimental data, taking into account good eyesight and the
experience and age-group determined to be typical for the Egyptian ‘\textit{Imy-r wnwt} priests who
would be performing these observations, suggest that the observers would have missed a first
crescent sighting 18-27% of the time.\textsuperscript{64} To further complicate things, the Egyptian calendar does
not start with the sighting of the first crescent, but rather with the disappearance of the
previous.\textsuperscript{65} Three correct observations must then be taken into account: the last crescent, the first
visibility and the invisible interval. As a consequence, Wells and others\textsuperscript{66} conclude that “none of
the Egyptian lunar dates offer any promise of yielding absolute dates.”\textsuperscript{67}

\textsuperscript{61} Borchardt 1935; Parker 1950; Krauss 1984; Luft 1992; Rose 1999
\textsuperscript{62} Wells 2002:461
\textsuperscript{63} Wells 2002: 451
\textsuperscript{64} Wells 2002:451
\textsuperscript{65} Parker 1950
\textsuperscript{66} Kitchen 2013; Shortland 2013
\textsuperscript{67} Wells 2002:470
Sothic Dates

The determination of Sothic dates relies on the observation of the first appearance each summer of the star Sirius, known as Sopdet in Egyptian and Sothis in Greek. Sothis appears as the brightest star in the sky, but is located close to the sun’s elliptical path. As a result, Sothis is only visible during part of each year, when it is not too close to the sun’s disk to be obscured by its glare, as opposed to circumpolar stars like Polaris that may be seen year-round. At some point, Sothis becomes visible at dawn in the eastern sky, an event referred to as the helical rising of the star.\(^\text{68}\) Coincidentally, this occurrence in Egypt corresponds with the onset of the annual Nile flood, rendering it a celestial timer for the most important event in the Egyptian year. Unsurprisingly, it was adopted as the date of the civil New Year.\(^\text{69}\) The Egyptian year was composed of three seasons, akhet, peret and shemu, each consisting of four months with 30 days per month. With the addition of five extra epagominal days, the Egyptian year came to 365 days. Unlike the Julian calendar, the Egyptians did not account for leap years, so four years after the helical rise of Sirius concurred with the start of the new year, the rising would slip one day and occur on the second day of the first month of the new year. The new appearance of the star would continue to incrementally slip until, after 1480 years, Sothis would rise once again on New Year’s day. This is referred to as the Sothic Cycle. Dating can thus be ascertained if the date that one of these cycles began can be determined and, as it were, such an event was recorded by the Roman author Censorinus. On the 21\(^{\text{th}}\) of July AD 140, according to Censorinus, Sothis rose on New Year’s Day by the Egyptian calendar (although the event has been astronomically calculated to the 20\(^{\text{th}}\) of July AD 139). With this known date, proponents of this dating method presume to be able to extrapolate the dates of earlier recorded concurrences of the rise of Sothis.
and the Egyptian New Year. Of course, the issue is not as straightforward as that. Ancient records that make mention of the rise of Sothis are rare, and none are without ambiguity. Even in the most reliable record, it is unclear whether the instance describes an actual observation or a prediction. Additional complications arise as, in order to ascertain a date, the exact latitude on which the historic observation took place must be known. The presence of climatic effects can affect the reliability of the observation, potentially resulting in several years’ difference for the derived date. If in the millennia of Egyptian history any calendar reform occurred, the whole process would be null. Ultimately, the system is fraught with too many unaccountable variables to determine an absolute date.

**Radiocarbon Dating**

When executed using best practices, radiocarbon dating offers an important albeit underutilized tool for Egyptology, including the ability to provide a test for historic chronology, to actively inform and resolve disputed dates, and to provide data for non-elite contexts outside the purview of the historical record. What radiocarbon cannot offer, at this point, is any better resolution—in terms of margin of error—than the historical record for Egypt’s chronology. At its most precise, radiocarbon dating of Egyptian material can give only a range of dates spanning, at minimum, decades. This resolution is far too broad for a highly nuanced historical record, especially when the reigns of multiple pharaohs and significant dynastic changes are known to have occurred within decades. Radiocarbon dating, especially when applied to archaeological samples of particular longevity (e.g. long-lived species of wood), is also susceptible to sampling

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70 Shortland 2013:27
71 Other scientific methods, such as thermoluminescence, offer no greater clarity than the historical record, with a margin of error between seven and twelve percent. (Manning 2006:352)
72 Of all known kings in ancient Egypt, half ruled for 10 years or less, a span far below the accuracy provided by radiocarbon dating.
and behavioral factors that may skew or obscure the data.\textsuperscript{73} If a specimen of carbonized wood from a 200-year-old cedar is recovered from an archaeological site in Egypt, depending from where in the growth sequence the sample was sourced, it could yield a radiocarbon date from anywhere along the tree’s two-century lifespan, hardly useful for refining the chronology. When the pyramids of Giza were subjected to extensive radiocarbon dating,\textsuperscript{74} the samples from Khufu’s Great Pyramid alone ranged over a 400-year period: the “old wood” problem in action.\textsuperscript{75} As it is highly unlikely that the historical chronology was several centuries in error, this revelation brought to light complicating questions of wood-use behavior in ancient Egypt including seasoning, stockpiling, and the reuse of old wood.\textsuperscript{76}

The resolution of the troublesome chronologies of ancient Egypt represents arguably the most significant and persistent issue in Egyptological studies. Pharaohs frequently reigned for less than ten years, significant events have yet to be pinned down, and with all current methods of dating, the margins of error are great.\textsuperscript{77} With greater temporal distance from the few fixed points and relatively well dated periods of the first millennium BC, errors compound and connections become increasingly tenuous. While the error of a few years in the New Kingdom may not seem so egregious, that minor inaccuracy grows to the order of a few decades by the Middle Kingdom, and more than a century by the Old Kingdom.\textsuperscript{78} In other words, dates may be off by generations. Radiocarbon dates calibrated against tree rings and other absolute dating techniques have error limits no better than synchronistically determined dates. Assuming best

\textsuperscript{73} Lehner et al. 1999; Schiffer 1986
\textsuperscript{74} Lehner et al. 1999
\textsuperscript{75} Schiffer 1986
\textsuperscript{76} Creasman 2014b
\textsuperscript{77} According to Kitchen (2000) the historical chronology has a margin of error that may be at best ±10 years, but is more frequently closer to ±25-50 years, and may be as off by as much as a century.
\textsuperscript{78} Kitchen 2000; Manning 2006
conditions and practices, Manning cites the highest possible precision margin for ancient Egyptian dates at within c. 10-20 radiocarbon years.\textsuperscript{79}

This high margin for error and plasticity in both chronologies render the established conventions incapable of providing the exactitude needed to advance our understanding of Egypt and its neighbors. Only dendrochronology can provide the annual, possibly even seasonal, precision to the timeline of Egypt and address questions of wood use behavior inaccessible by other means.

\textit{Dendrochronology}

Dendrochronology is the study of the chronological sequence of annual growth rings in trees. The science was developed in the early twentieth century by astronomer Andrew Ellicott Douglass, who first sought to use the record of climatic reactions registered in the anatomy of certain trees to study cycles of sunspot activity.\textsuperscript{80} Applications for the field abounded, drawing from the chronological, ecological and climatological data stored in tree rings. Tree rings are routinely used to date archaeological objects and features, and provide timelines of habitation or construction and render checks for relative dating techniques.\textsuperscript{81} Although the chronometric application has the greatest longevity and popular recognition, environmental tree-ring studies are among the most broadly applied worldwide.\textsuperscript{82} Reconstructable signals include, but are not limited to, precipitation, temperature, stream flow, drought severity, and insect infestation. From a dendroarchaeological perspective, these records can provide invaluable insight into the cause-effect relationships between environmental and historical disturbances. Furthermore, a relatively

\textsuperscript{79} Manning 2006:329  
\textsuperscript{80} Webb 1983  
\textsuperscript{81} Bannister 1963  
\textsuperscript{82} Nash 2008
recent vein of research into the exploration of wood use behaviors demonstrates the capacity of trees and wooden objects to inform our understanding of wood-use practices, trade and other economic variables and relationships.\textsuperscript{83}

Principles of Dendrochronology\textsuperscript{84}

Trees grow both upward (apical growth) and outward (radial growth). The latter occurs as a result of the division of a thin circumferential layer of cells referred to as the cambium into two secondary tissue types (Figure 8). Cells formed to the outside of the cambium differentiate into phloem, while those formed to the inside become xylem, or the woody part of the tree. It is in the xylem that annual rings are formed and dating may be performed, although the presence or absence of phloem can be used to determine if a sample is intact up to its last (most recent) growth ring in the absence of bark. On the other end, the pith, or central core of the tree around which the xylem grows in the stem and branches, may serve as a marker for the initiation of growth; its presence insures that the earliest formed rings are present in the sample. In conifers, tissue is composed mostly of tracheids, long thin cells running parallel to the long axis of a stem or branch. Annual rings are visible as a result of the differentiated growth of early and late wood. Early wood refers to the tracheids formed at the beginning of the growing seasons, during the period of rapid radial growth, that are characterized by thin cell walls and wide open cavities. Latewood occurs at the end of a growing season when cambial activity slows and the tree transitions into dormancy. The cell walls of latewood tracheids are thicker, appearing darker as the cavities shrink. When growing conditions become favorable once again, the tree resumes the invigorated early wood growth characteristics.

\textsuperscript{83} Dean 1996; Nash 2008
\textsuperscript{84} For detailed discussions see Fritts 1976; Schweingruber 1993
The sharp contrast between the last latewood cells and first early wood of the following season creates the distinct ring boundary. Dendrochronology is made possible by the fact that many, although by no means all, trees exhibit characteristic patterns in the sequence of growth rings, recognized by variations in the rings’ relative thickness, corresponding to local and regional growth factors (Figure 9). Broad rings represent a productive growth season precipitated by favorable conditions, whereas smaller rings reflect a fluctuation in growth limiting factors that resulted in poorer (or even non-existent) growth seasons for the tree.

In order to be datable through dendrochronological techniques, an individual tree must meet four criteria. The first is that the tree must only produce a consistent and predictable number of rings each growing season (which in most trees and regions amounts to one per year).

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85 Douglass 1941
86 see Stokes and Smiley 1968
Figure 9: Regional factors limiting growth will produce a recognizable pattern in the varying ring widths that may be matched against a master chronology to anchor the ring sequence to absolute time (R. Caroli).

Ring growth generally expresses itself in one of four ways: anatomically indistinct rings, multiple rings per year, annual rings, and in sequences of multiple missing rings. During average years a tree will initiate growth when climatic conditions are favorable (e.g. when temperatures become warmer or a regular rainy season commences). As the season progresses, conditions become less conducive (e.g. cooling temperatures, termination of rain), at which point cell growth will become increasingly more stunted and ultimately stop, to be reinitiated the following season. This annual cycle produces one growth ring composed of early and late wood (Figure 10). Should, however, a tree experience a particularly stressful year it may fail to grow at all during a season, or only grow partially, which results in a “missing” or locally absent ring.87

Missing rings occur occasionally in most species of trees and can be accounted for through crossdating, or comparison with other trees of the same species growing during the same period.

87 Stokes and Smiley 1968
Some species however, have a predilection for producing many missing rings, which can make dating such trees arduous or even impossible.\textsuperscript{88}

![Cross-section of tree showing differentiation between early and late wood (R. Caroli)](image)

Figure 10: Cross-section of tree showing differentiation between early and late wood (R. Caroli)

Alternatively, a tree may produce more than one growth ring in a year, a phenomenon that results when atypical climate conditions (e.g. a sudden freeze or unseasonal rain) prompt growth to stop or restart prematurely. These “false” rings appear as intra-annual bands and, if not properly identified by their characteristics and through crossdating, have the potential to skew the determined dates for the tree. Large sample depth is essential for identifying and resolving these issues.

Secondly, the tree can only have one environmental factor dominant in limiting its growth. In the arid southwestern United States, the limiting factor is usually precipitation,

\textsuperscript{88} Nash 2008
whereas in northern Europe or at higher altitudes or latitudes, growth is frequently limited by temperature. These two parameters are predominant in most temperate and boreal zones; however, other limiting factors are being identified in other parts of the world, such as the tropics, where a dominant limiting factor was previously not thought to exist.\textsuperscript{89}

Third, the growth-limiting factor must vary in intensity from year to year. This variability must too be reflected faithfully in the resulting annual rings’ widths. This produces a recognizable sequence necessary for making crossdating possible. Any particular pattern is never exactly repeated over a long enough time period, making only one match possible. Essentially, if conditions are too stable or externally controlled, as in an irrigated garden, growth rings will exhibit a high degree of regularity, with every year demonstrating an even width (Figure 11).

Figure 11: Complacent growth (left) marked by little variation in ring width versus sensitive growth (right), which forms a demonstrable pattern in ring widths.

Crossdating cannot be successful without a distinct pattern of smaller or larger rings, representing relatively productive or stunted growth seasons. Trees that produce a strong pattern

\textsuperscript{89} e.g., Trouet et al. 2009
are termed “sensitive” (i.e. they faithfully respond to the variable local climate signal), whereas trees with uniform ring widths are referred to as “complacent.”

Lastly, the variable environmental growth-limiting factor must be uniformly effective over a large geographical area, or at least large enough to incorporate sufficient trees to make comparisons viable. This is necessary for the creation of broad composite chronologies, whereby trees growing many kilometers apart may be crossdated.90 For archaeological wood, the exploited species must demonstrate all of these criteria and be preserved well enough and in large enough quantities to present a crossdatable sample from which to build a sequence.91 This is further complicated by the fact that in order to be crossdatable, the obtainable samples must exhibit sufficient rings to display a unique and identifiable pattern. In the American Southwest, this amounts to a minimum of c. 30 rings per sample. Where sequences are less recognizable or patterns develop over a larger time scale, the minimum number of rings needed to successfully crossdate becomes greater. The longer the cultural time span, the greater the quantities needed over the entire historical range.

Chronology Building

The construction of a chronology based on tree rings is predicated upon the principle of crossdating.92 By pattern matching ring widths from trees with partially overlapping lifespans, one can extend a chronology, ultimately pinning the sequence to a sample of known age (e.g., a living tree), so that every ring in the sequence is attributed to an exact calendrical date (Figure 12). Without a sample of an exact known age, these sequences exist as “floating chronologies” that hover in relative time until connection with an absolutely dated sequence can be established.

90 Douglass 1941
91 Bannister 1963
92 Douglass 1941
The chronology of pharaonic Egypt cannot be securely dated via a dendrochronology unless it can be grounded in real time. As a result, wooden material is required not only from the period in question, but also from the more recent (and well-dated) Ptolemaic, Roman, Islamic and historic periods. Construction of a chronology will necessarily mandate a laborious process of collection and sampling for the five millennia of history back to predynastic Egypt, however the continuous archaeological and historical use of native wood makes viable the endeavor.

Figure 12: The use of native Egypt species has been archaeologically identified in the construction of structures, ships, coffins, domestic items and more from the predynastic period through to the Islamic period. Living trees in Egypt such as *Acacia* spp. and *Ficus sycomorus* may date back to at least the Mamluk period of Islamic Egypt (c. AD 1350), bridging the gap between the Middle Ages and the present.

After a master chronology, or an absolutely dated sequence that extends from the present back to (and beyond) the period of significance for a particular culture, has been created, any
sample collected can then be compared to this master sequence in the hopes of obtaining a match and thus its exact dates. Assuming the previous conditions can be met, dendrochronology provides the most accurate, precise, and reliable chronometric information currently available to archaeologists.
Chapter III. Dendrochronological Potential in Egypt

For decades it was thought that the criteria needed to perform dendrochronological dating could not be satisfied outside of temperate and boreal regions. These climates are optimally conducive for tree-ring research as the distinct seasonality characteristic to these areas yields clearly defined annual growth rings in many tree species. With decreasing distance to the equator, annual cycles in temperature and light availability weaken. Instead, cycles are more apt to be defined by less seasonally dependent parameters, such as water availability, often resulting in the formation of indistinct, non-annual rings. These conditions were long seen as prohibitive to the application of dendrochronology outside of the temperate and boreal zones, such as in the Mediterranean and tropical regions. In the last 10 years, however, dendrochronology has expanded to the Mediterranean basin, the Near East, Asia, and the wet tropics, where ring formation tends to depend on periodic droughts, flooding and/or temperature. Research in the dry tropics of Africa, however, has remained fragmentary.

In order to determine the dendrochronological viability of tree species in areas that seemingly cannot crossdate or lack a strong, known periodicity, assessment measures have been derived including the monitoring of cambial activity, post-mortem ring counts of trees of known ages, radiocarbon dating and stable isotope analysis. Studies have shown that seasonality in tropical regions has been “grossly underestimated.” Advances in areas previously thought

93 Worbes 2002; Wils 2010
94 see Stahle et al. 1999; Worbes 2002; Cherubini et al. 2003; Wils 2010
95 e.g., Esper et al. 2007; Touchan et al. 2008, 2010; Trouet et al. 2009
96 e.g., Touchan et al. 1999; Pourtahmasi et al. 2007
97 e.g., Bräuning and Mantwill 2004; Treydte et al. 2006; Grießinger et al., 2008; Shao et al. 2010
98 Cherubini et al, 2003; Brienen and Zuidema 2005; Jones et al. 2009; Buckley et al. 2010; D’Arrigo et al. 2010
99 Wils 2011:346
100 Worbes 1995; Verheyden et al. 2004; Couralet et al. 2005; Anchukantis et al. 2008; Wils 2011
101 Maingi 2006:182
inaccessible demonstrate the need to actively assess viability in the species and areas in question, rather than operating based on assumptions.

HISTORY OF PAST DENDROCHRONOLOGICAL EFFORTS IN EGYPT

The idea of establishing a dendrochronology for ancient Egypt is a pursuit not without certain pedigree. As early as the science was founded, sorties have been made by prominent dendrochronologists (e.g., Douglass, Haury, Bannister, Dean) into the dating of ancient Egyptian material. Results of these casual inquiries revealed positive evidence for further pursuit of tree-ring science in Egypt based on imported conifers, but stagnated beyond this point. Progress was hampered by a confluence of external factors, not the least of which was the lack of any dedicated dendrochronologists whose research interests lay in ancient Egypt. In the waning years of the 20th century, Egyptian specimens were examined piecemeal, demonstrating viability, but never undertaken as a definitive, comprehensive effort. Peter Kuniholm in 2001 substantiated the efficacy of ancient Egyptian wood by crossdating the remains of a cedar coffin with a floating chronology developed from the timber of royal boat. With the question of crossdating imported wood found in Egyptian archaeological contexts positively answered, the first concerted effort towards producing a dendrochronology for Egypt was initiated, as part of the joint archaeological and chronological undertakings of the Synchronisation of Civilisations in the Eastern Mediterranean in the Second Millennium BC (SCIEM 2000 Project). By sampling cedar objects in worldwide museums using primarily non-invasive scanning methods and charcoal produced from ongoing archaeological excavations, the project produced a series of floating

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102 See Creasman 2014a
103 Creasman 2014a
104 Kuniholm 2001a, 2001b
105 Creasman 2014a; Manning et al. 2013
chronologies.\textsuperscript{106} As noted by Creasman,\textsuperscript{107} the foundational work determining the
dendrochronological potential for ancient Egypt has been established, but “there has been no
effort to collect or analyze tree-ring materials in or from Egypt with the organization or
frequency necessary to contribute to larger chronological, behavioral, or environmental analyses
for any period of its history.”

Until recently,\textsuperscript{108} all efforts have been exclusively confined to the study of cedar and
other imported timber. These species, which have the necessary characteristics to crossdate, have
great potential to address questions of wood use in ancient Egypt and the Near East, including
stockpiling, seasoning, trade and economics. It is precisely these issues of behavior that also
cloud any timeline expensive imported species would create. Imported wood was valuable and
finite. The ancient Egyptians practiced methods of conservation and reuse that serve to further
and further remove the use and ultimate depositional context of imported timbers from the last
possible dates that may be dendrochronologically derived from them, i.e. their cutting dates.\textsuperscript{109} In
the Great Pyramid of Giza, wood \textsuperscript{14}C dated to centuries before the expected construction dates of
the monument, while cedar used in the construction of royal funerary vessels show obvious
indicators of reuse.\textsuperscript{110} In both cases, these are elite contexts associated with the pharaoh that
demonstrate no lack of resources nor expense spared. The use of old wood reflects an inherently
Egyptian practice of valuation and sustainability that is not yet fully understood. It is currently
unknown whether wood use behavior for native species was appreciably different than that for
imported species.

\textsuperscript{106} Cichocki 2000, 2006
\textsuperscript{107} Creasman 2014a:87
\textsuperscript{108} Andersen and Krywinksi 2007
\textsuperscript{109} Creasman 2013; A cutting date represents an ideal and seldom found grail in archaeological wood, as so often
age and processing has resulted in the loss of the outer ring layers. More often, the dates derived from archaeological
wood will be temporally removed by several years from the terminal growth ring produced by the tree, adding
further unknowable time between the latest determined date for the wood and the actual year or years of its use.
\textsuperscript{110} Haldane 1984; Creasman 2010
Whereas Near Eastern practices concerning wood use are relatively ambiguous, Egypt benefits from a robust visual record of the treatment and exploitation of indigenous trees to aid in the interpretation of wood use behaviors. It is known that astute Egyptian carpenters practiced seasoning to avoid cracking during and after construction.\(^{111}\) With conifers, in the far wetter environments such as Lebanon, drying the beams prior to export (evidence indicates they were exported as processed beams rather than whole felled trees\(^{112}\)), would have taken an unknown, but potentially lengthy period of time. In the extremely arid climate of Egypt, however, seasoning of their native species would have been an incredibly brief process (slowed in fact by the covering of timber to protect it from the sun and open air lest rapid drying weaken the wood).\(^{113}\) Furthermore, the climate signals registered by Lebanese, Levantine and other imported wood can give no indication of the relationship between environmental factors and the history of Egypt, except perhaps in the case of rare, catastrophic interregional climatic events like the eruption of Thera.\(^{114}\) Hypotheses that posit environmental determinates for social upheaval in ancient Egypt, including the weakening of the state during its three intermediate periods of division and foreign conquest, require evidence that only trees reflecting a local climate signal could provide. Nile flow reconstructions, droughts, floods and pestilence are all factors that could be elucidated by dendrochronology, but only for species actually growing in Egypt.

**APPLYING DENDROCHRONOLOGY IN EGYPT**

As evidenced above, Egypt demonstrates a great need for a local dendrochronology, but the question of plausibility remains: can dendrochronology be reasonably applied for native

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\(^{111}\) Pepler-Harcombe 2011:81  
\(^{112}\) Pepler-Harcombe 2011:81  
\(^{113}\) Pepler-Harcombe 2011  
\(^{114}\) Manning 2003
Egyptian timber? In order to be possible, the following parameters (previously outlined) must be met:

- There must be a large enough quantity of preserved wood across the millennia of Egyptian history from which to sample
- The wood must be well-preserved enough to be viable for analysis
- Wood must be accessible for the sampling requirements
- The amount of rings present on a sample must be sufficient for pattern recognition
- The species used must fulfill the four criteria requisite for the successful application of tree-ring studies
  - The wood must produce one annual ring
  - Growth is affected by one dominant limiting factor
  - The wood must be sensitive
  - The samples must be crossdatable across a region

**Availability**

As early as the 1920s, A. E. Douglass, in correspondence with prominent Egyptologists, had concluded that there was at that point enough wood material in the ancient Egyptian collections of world museums to provide the basis for the construction of an Egyptian dendrochronology. Hundreds of tons of wood reside in museums, a significant portion of which are demonstrably sycamore, tamarisk and acacia, and more wood, including charcoal, is extracted from the numerous ongoing investigations in Egypt annually. From the pharaonic period, native wood was continuously exploited in architecture, boat construction, and in

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\(^{115}\) Lucas and Harris 1962; Kuniholm 1997; Chickoki 2006; Gale et al. 2010; Creasman 2013, 2014a
household and ritual or funerary items. While the pharaonic period benefits from the Egyptian ritual practice of amply provisioning the deceased, sources of wood are continuously available from the archaeological and historical record, bridging the gap between the pharaonic period and modern trees. In the subsequent Ptolemaic and Roman periods, Greeks and Romans built prodigiously across Egypt, maintaining Egyptian traditions in funerary provisions and sourcing both native and imported wood to service their new infrastructure, temples and populations. Use of wooden coffins persisted, along with wooden mummy portraits, which were frequently sourced from local wood (*Ficus sycomorus*). A significant number of Greek and Roman shipwrecks have been identified off the coast of Alexandria, some of which must (and do) contain wood from native Egyptian species either in their original construction or repairs.

While the Roman period reflected an increased reliance on imported wood, the use of native Egyptian species surged during the Islamic period. Houses, mosques, aqueducts and other architectural edifices from the subsequent Islamic period were constructed of wood, as were boats and myriad decorative, domestic and furniture pieces. Extant structures from the historic period are expected to yield native timber, and the living trees of Egypt may range in age from 75 to 1000 years depending on the species. There is, beyond a doubt, a broad enough collection of native Egyptian wood in extant collections, store rooms and architecture both ancient and historic to make headway in the development of a dendrochronology, should the indigenous species prove viable.

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116 DiTomaso et al. 2013
117 Sandrin et al. 2013
118 At the port site of Quseir al-Qadim in Egypt, 32% of the wooden Roman artifacts were made from local native wood (namely *Ficus sycomorus, Tamarix* spp. and *Acacia* spp.) as compared to 60% of the Islamic period artifacts. Of the charcoal recovered from the site, 56% of the wood was native during the Roman period while 81% was local during the Islamic period. While some of this charcoal was locally sourced for the purpose of burning, much of the material reflects the recycling of wood from ships and domestic items, further suggesting an increased use of local timber in construction during the Islamic period (Van der Veen et al. 2011:221).
119 Van der Veen 2011
**Preservation**

The ancient Egyptian belief in the afterlife led the elite to ritually provision their dead with all manner of grave goods, from possessions used in daily life, to representational models of necessary goods and services. Many of these items were of wood, and of these, a fair percentage was local wood. Because they were buried in antiquity in the hyper arid deserts beyond the reach of the Nile’s floods and modern settlements (until very recently), the contents of these tombs have been remarkably well preserved and in staggering quantities. With the dry climate directly promoting the preservation of organic matter, issues of decay are not as prevalent as in more humid areas of the world; however, Egyptian material is not impervious to some level of rot and deterioration. Monsoonal rains periodically caused tombs to flood in antiquity, bringing moisture sufficient for the prosperity of brown and soft rot fungi. Overall the three most common forms of degradation of archaeological wood from ancient Egypt are: soft rot, which is typified by the formation of cavities within secondary cell walls; brown rot fungal decay, resulting in swollen, porous cell walls; and nonbiological deterioration including the formation of cracks and fissures, generally in response to chemical interactions with limestone, gypsum sodium chloride or moisture. In general, preservation of wood is remarkably favorable, and of relatively little concern as an impediment for successfully performing tree-ring studies.

**Accessibility**

It is not uncommon for museum conservationists and curators to balk at the question of sampling. In fact most, although not all, museums around the world patently prohibit invasive

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120 Pepler-Harcombe 2011:236
121 Blanchette et al. 1994
sampling methods for their artifacts.\textsuperscript{122} This reluctance must be overcome, especially given that thousands of non-diagnostic pieces of wood permanently reside in storage magazines, never to be curated or (especially in the case of Egypt), even examined. Even if diagnostic and intrinsically valuable pieces are not considered, there is still an enormous collection from which to draw. Previous work on Egyptian material by the SCIEM (2000) project has employed the use of innovative, noninvasive techniques, including the use of flat bed scanners to digitally record ring patterns from flat surfaces such as coffins.\textsuperscript{123} These methods warrant further trials and development; however, they will still only be applicable on certain objects with exceptionally fine surfaces. Acquired samples must also be large enough to be crossdatable. Investigations into living trees in Egypt will, if possible, provide an approximate minimum for determining periodic patterns in ring formation, but a requirement of at least 50 rings should be expected. With too small of a sample, the patterns exhibited in the ring growth may match fairly well to multiple sequences across the master chronology. A longer sequence contains more pointer years and indicative variations insuring that the pattern can be matched to the correct spot. Considering that even in highly favorable conditions for dendrochronology, such as in the American Southwest, more than 30 rings are needed to reliably date a sample, this may immediately preclude sampling of smaller artifacts, narrowing the corpus of viable material. An additional consideration is that, because Egyptian antiquities law forbids the export of any archaeological materials or scientific samples, all research of materials sourced in Egypt presently must be done in country. This is hardly prohibitive considering the relative ease and lack of expense inherent to tree-ring studies, as compared with other scientific dating techniques. With the expected

\textsuperscript{122} Creasman 2014a
\textsuperscript{123} Cichocki 2000, 2006
satisfaction of these three provisions, the deciding factor then becomes whether or not the most 
common native tree species from ancient Egypt are dendrochronologically viable.

Chapter IV. Viability of Indigenous Egyptian Tree Species

The three native trees with greatest representation in the Egyptian archaeological and art 
historical record are the Egyptian sycamore (Ficus sycomorus)\(^{124}\), tamarisk (Tamarix spp.) and 
acacia (Acacia spp.). Characterized as dicotyledons growing outside of a temperate or boreal 
zone and presumed, at least at some point, not to date,\(^ {125}\) none of these species represent obvious 
candidates for dendrochronology.\(^ {126}\) As rigorous testing of Egyptian specimens has never been 
undertaken (or sufficiently reported), the expected ability of these species to exhibit pertinent 
wood anatomical characteristics will be evaluated and their potential utility for tree-ring studies 
assessed based on a review of relevant literature. The first attempt to systematically analyze 
these trees has been initiated in a study funded by the National Science Foundation beginning 
with the collection of samples from living trees across Egypt in January 2015.

FICUS SYCOMORUS (see Appendix C)

The most significant tree to the ancient Egyptians, demonstrated both by its copious 
exploitation and preeminent position in Egyptian art, iconography and mythology, was arguably 
the sycamore (Ficus sycomorus), known to the Egyptians as nht.\(^{127}\) Sampling of Egyptian

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\(^ {124}\) Not to be confused with the North American (Acer platanoides) and Eurasian (Acer pseudoplatanus) species of maple, commonly referred to by the same name, the Egyptian sycamore refers to a species of fig tree indigenous to the region.

\(^ {125}\) Fritts 1976; Grissino-Mayer 1993

\(^ {126}\) Kuniholm et al. 2014

\(^ {127}\) Breasted 1906; Weeks 2003
collections from major world museums has consistently demonstrated the favored use of *Ficus sycomorus*, appearing in greater quantities than any other species, both native and imported.\(^{128}\) One of the principal species in desert borderlands, *Ficus sycomorus* naturally occurs all over eastern Africa, ranging from Sudan south to South Africa and as far east as Yemen, although cultivation of the sycamore fig has been almost exclusively an Egyptian specialty.\(^{129}\) Remains of *Ficus sycomorus* begin to appear in Egypt in Predynastic times, with earliest records emanating from Naqada I (3900-3650 BC) sites, and from el Omari (c. 3200 BC).\(^{130}\) Shortly thereafter, the tree begins to appear in great quantity from Egyptian excavations, and was a valued domesticant in the lower Nile Valley from the start of the third millennium BC onward.\(^{131}\) In the Roman period, *Ficus sycomorus* was commonly used for the so-called “mummy portraits,” images of the deceased that were painted on slices of wood and placed over the heads of their prepared mummies. These boards were cut radially from the source trees or beams, potentially allowing, as with the examination of AD 17\(^{th}\) century panel paintings, the rings to be observed and counted.\(^{132}\)

Taller than a true fig, the tree produces sweet, although small, syconia and broad, durable timber. In the wild, pollination occurs as a result of a specific symbiotic wasp, *Ceratosolen arabicus* Mayr, although since the tree began to be cultivated, propagation is clonal and fruit production is no longer dependent on a pollinator. Instead, fruit maturation in ancient Egypt was artificially induced by lacerating the surface of young syconia, as evidenced by depictions in tombs and preserved fruit remains.\(^{133}\) Thought to have a lifespan of 500 to 1000 years, *Ficus*

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\(^{128}\) Cichocki 2000  
\(^{129}\) Hughes 1992; Zohary and Hopf 2000  
\(^{130}\) Gale et al. 2000; Zohary and Hopf 2000  
\(^{131}\) Zohary and Hopf 2000:266; Weeks 2003  
\(^{132}\) Cartwright et al. 2011  
\(^{133}\) Zohary and Hopf 2000:265-266
sycomorus may grow to a massive size for a desert species, reaching a height of 20 to 50 meters and width of 6 meters. As a result of their size, Ficus sycomorus trees were valued sources for timber, but their spongy, coarse-grained wood left something to be desired for construction and furniture craft (Pepler-Harcombe 2011:34). The lightweight, fibrous nature made the wood ideal for the construction of boats and the soft, durable wood was widely used for coffins and general woodwork in ancient Egypt through to the Islamic period.134

Wood Anatomy135

As described above, the wood of Ficus sycomorus is coarse and fibrous, exhibiting a pale, sometimes yellow color. Ficus sycomorus is a diffuse-porous wood, with vessels occurring in short radial rows or in small clusters. Parenchymal bands were recorded, as well as the occasional presence of prismatic calcium oxalate crystals located within the bands.136

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134 Pepler-Harcombe 2011; Van der Veen 2011; Blakemore 2006; Gale et al. 2000; Hepper 1990:58; see Table 3 (Appendix C)
135 see Fahn et al. 1986; Schweingruber 1990; Cartwright and Middleton 2008
136 Cartwright and Middleton 2008:66
The growth rings that *Ficus sycomorus* produces are dark, highly visible and fairly circular, distinguishable from the lighter, wavy and narrow zones between the bands of confluent parenchyma.\(^{137}\) Ring boundaries are also determinable by a marked absence of banded confluent parenchyma.\(^{138}\) Despite demonstrating fairly good ring boundaries and circuit uniformity, however, ring wedging is extremely frequent, with many growth rings merging into each other.\(^{139}\) As a result, consistent ring counts could not be determined, differing by two to three rings between radii on the same sample.\(^{140}\) The difficulty in unequivocally locating ring boundaries, especially in the area around the pith, renders *Ficus sycomorus* an unlikely candidate for the pursuit of a native Egyptian dendrochronology. Furthermore, sycamore was a cultivated commodity in ancient Egypt.\(^{141}\) Extensive legislation is recorded pertaining to the planting, watering, maintenance and harvesting of these protected trees.\(^{142}\) Remains of sycons have been found bearing characteristic gashes, indicative of forced ripening, lending credence to the notion that the cultivation of these trees was highly controlled.\(^{143}\) It would not be an unreasonable assumption that, even if a method of dating were developed, most *Ficus sycomorus* in Egypt would exhibit complacent growth with no demonstrable environmental signal, due to their history of artificial management.

**Literature Review**

\(^{137}\) Maingi 2006:196
\(^{138}\) Maingi 2006:196
\(^{139}\) Maingi 2006:197
\(^{140}\) Maingi 2006:197
\(^{141}\) Weeks 2003
\(^{142}\) Hughes 1992:19
\(^{143}\) Gale et al. 2000; Scott 1965
Publications concerning the dendrochronology of *Ficus sycomorus* are sparse, likely owing to the fact that attempts at dating *Ficus sycomorus* have found that its characteristic anatomical features seem to preclude the utility of this tree for dating purposes. Anecdotally, this species has widely been acknowledged to be undatable by dendrochronologists pursuant to several unpublished attempts by Bannister and others. In recent years, published analyses of the anatomy of *Ficus sycomorus* from ancient Egyptian mummy portraits and live trees in east Africa have corroborated these claims. Dendrochronology was not specifically considered in the anatomical description recorded by Cartwright and Middleton, the purpose was purely for species identification, and only three samples were tested in the Kenyan study. The great wealth of archaeological wood available, combined with copious textual resources pertaining to the treatment of sycamore in ancient Egypt and the lack of in-depth study justify a comprehensive assessment of *Ficus sycomorus* in the Egyptian context. It is unlikely at this point that the species will be determined to be dendrochronologically viable; however, it can only be patently dismissed after due diligence is done.

TAMARIX (see Appendix D)

Of great abundance in the Egyptian deserts are trees of the genus *Tamarix*, although by virtue of their generic anatomy, individual species or subspecies are reportedly nearly impossible to discern without leaves. The range of species naturally occurring in Egypt includes *Tamarix aphylaa*, *T. tetragyna*, *T. nilotica*, *T. amplexicaulis*, *T. passerinoides*, and *T. macrocarpa*. Of

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144 Creasman 2014a
145 Maingi 2006; Cartwright and Middleton 2008
146 Cartwright and Middleton 2008
147 Maingi 2006:197
148 Preliminary examinations of specimens of *Ficus sycomorus* collected from living trees in Egypt in January 2015 show no indications of being datable using current methods.
149 Zohary 1966
these varieties, the two most common species are *T. nilotica* and *T. aphylla*, found throughout the *wadis* of the western and eastern deserts and, to a lesser extent, within the Nile Valley.\(^{150}\) While *T. nilotica* is a short, shrub-like tree generally lacking a stem width suitable to yield serviceable timber, *T. aphylla* represents the largest iteration of its genus, growing up to 18 meters tall. Individual tamarisks may live 75 to 100 years or more, although the specific longevity of Egyptian tamarisk may need verification.\(^{151}\) Able to tolerate a relatively high level of soil salinity, the trees grow together in dense thickets alongside and in the beds of dry *wadis* where few other plants are able to propagate.\(^{152}\)

*Tamarix*, possibly referred to as *jsr* by the ancient Egyptians was portrayed in tomb and temple artwork, and was sacred to the god Re, referred to in the *Book of the Dead* as “the great god inside the *jsr*.”\(^{153}\) Leaves, twigs and flowers from *Tamarix* trees have been identified in tombs and archaeological contexts.\(^{154}\) The Harris Papyrus records 3,270 bundles of *jsr* that were presented to Amun-Re as offerings, and 390 bundles dedicated to the “gods and goddesses, the lords of South and North.”\(^{155}\)

Although unable to yield long straight timbers, *Tamarix* spp. wood was dense and easily worked, rendering it widely used by the ancient Egyptians for carving and construction elements such as spokes, dowels and joints for chariots, boats, furniture and other crafts.\(^{156}\) Other artifacts identified as tamarisk include caskets, boxes, bows and arrows.\(^{157}\)

\(^{150}\) Western and McLeod 1995:89
\(^{151}\) DiTomaso et al. 2013
\(^{152}\) Zohary and Hopf 2000
\(^{153}\) Davis 1894
\(^{154}\) Gale et al. 2000
\(^{155}\) Breasted 1906:177
\(^{156}\) Hepper 2009:49; Pepler-Harcombe 2011
\(^{157}\) Gale e al. 2000; Hepper 2009:40; see Table 4 (Appendix D).
Wood Anatomy\textsuperscript{158}

*Tamarix* spp. produce wood that varies in color from a dark brown to deep gold. It is diffuse-porous, with paratracheal and fusiform axial parenchyma present in vasicentric or confluent distributions. Multiseriate rays, 5 to 20 cells in width occur with prismatic crystals occasionally appearing within their cells.\textsuperscript{159} Of the undetermined species of tamarisk whose anatomy was examined in thin-section by Cartwright and Taylor,\textsuperscript{160} growth ring boundaries were indistinct, although *Tamarix* spp. across Africa and the Near East have been found to produce visible and distinct growth rings.\textsuperscript{161}

![Figure 15: Growth rings on specimen of *Tamarix aphylla*](http://insidewood.lib.ncsu.edu/search [May 2, 2015]).

\textsuperscript{158} See Zohary 1966; Hepper 1981; Boulos 1999
\textsuperscript{159} Cartwright and Taylor 2008:82
\textsuperscript{160} Cartwright and Taylor 2008:82
\textsuperscript{161} Zohary 1966; Fahn et al. 1986; Yang et al. 2010
For some time, tamarisk resided among the large list of trees that were not known to produce annual growth rings.\textsuperscript{162} It was thought that, within a single growth season, tamarisk would be as likely to produce multiple rings, a discontinuous ring, or no ring at all as it would be to reliably form a single annual ring.\textsuperscript{163} Despite encouraging studies in the American Southwest and reported successes in China, tamarisk remains a genus that is still widely discounted in most regions. As yet, no dendrochronological assessment has been performed on Egyptian \textit{Tamarix} spp. The following literature review confirms that in certain environments dating is possible, although not without extensive caveats.

\textit{Literature Review}

In 1984, Hereford produced a report\textsuperscript{164}, which questioned the inability of tamarisk to produce reliable annual growth rings. Rather, Hereford\textsuperscript{165} claimed “considerable accuracy” in dating and correlating flood-plain deposits with the assumption of reliable ring counts for tamarisk. In the 16 samples analyzed, Hereford\textsuperscript{166} found “abundant evidence” that growth rings in species of tamarisk growing in the Little Colorado River Valley, were in most cases, annually produced, modulated by freezing winter temperatures. Hereford performed annual measurements for three years which corroborated that, at least for those three growth seasons, one annual ring was produced.\textsuperscript{167} Using historical photographic evidence, tamarisk stands were compared to datable cottonwood trees growing concurrently. The dates obtained from the tamarisk trees corresponded well with the expected dates obtained from the contemporaneous cottonwood.

\begin{thebibliography}{9}
\bibitem{162} Fritts 1976:14
\bibitem{163} Hereford 1984:662
\bibitem{164} Hereford 1984
\bibitem{165} Hereford 1984:662
\bibitem{166} Hereford 1984:662
\bibitem{167} Hereford 1984
\end{thebibliography}
Lastly, using historical evidence and the earliest date obtained from a tamarisk specimen, Hereford determined an expected earliest date for the establishment of the studied tamarix stand.\textsuperscript{168} Had the sampled trees been regularly producing multiple intra-annual rings, Hereford postulated that at least one would have shown a false date pre-dating the expected period of establishment. The samples were analyzed at the University of Arizona Laboratory of Tree-Ring Research by Jeffrey Dean, who, in correspondence with Hereford,\textsuperscript{169} determined the samples to be suitable for crossdating.

After this early venture, other studies of invasive tamarix in the American Southwest proliferated, becoming increasingly common in the new millennium. A study was performed on species of \textit{Populus} and \textit{Tamarix} in the Colorado River basin with limited results for the dating of tamarix.\textsuperscript{170} Nonetheless, it served as a point of departure for subsequent studies in tamarix establishment. Friedman\textsuperscript{171} used tamarix to determine that floodplain sediments could be precisely dated based on changes in the trees’ ring anatomy upon burial. Combining observations of these anatomical reactions with tree-ring counts, Friedman was able to reliably date sedimentary beds larger than 30 cm thick to within a year of deposition. Birken and Cooper\textsuperscript{172} sought to investigate the hydraulic and geomorphic influences on tamarix establishment, but ran into problems performing dendrogeomorphic analyses as a result of the anatomical changes discussed by Friedman.\textsuperscript{173} Ring counts were determined to be reliable in areas of the trees’ normal growth, but grew increasingly difficult in buried parts from where Birken and Cooper were attempting to sample the germination point. Multiple ring counts were necessary in order to

\textsuperscript{168} Hereford 1984:662
\textsuperscript{169} Hereford 1984:663
\textsuperscript{170} Cooper et al. 2003
\textsuperscript{171} Friedman 2005:1077
\textsuperscript{172} Birken and Cooper 2006
\textsuperscript{173} Friedman 2005
circumvent the difficulties of partial rings, which were widely present. 174 Whitcraft 175 reported being able to crossdate growth rings in tamarix using standard dendrochronological techniques outlined by Stokes and Smiley 176 and utilized in previous tamarix studies. 177

A further study of tamarix in the Grand Canyon (Arizona, USA) sought to determine the relative influences of climate and hydrology on plant establishment. 178 A landscape-level tree-ring analysis was performed in which 409 tamarix individuals were sampled. Although radii from individual specimens reliably crossdated with each other, the samples were unable to crossdate among most tamarisk individuals owing to rampant affliction with heart rot, insect damage, and compressed rings from burial. 179 By scanning and measuring the samples, Hultine et al. 180 were able to date cross sections of living and dead tamarix trees, likewise in the American Southwest.

Internationally, reports of exploring the datability of tamarix have been noted from Spain and Portugal. 181 In China, dendrometric and micro-coring methods were used to analyze the growth dynamics in ring formation of Tamarix ramosissima. The authors concluded that the annual rings of tamarix could viably be used to reconstruct the determining processes that govern water regimes within the study region.

Overall, research during the past decade demonstrates that, in at least certain regions and climates, Tamarix spp. may produce annual growth rings, but dating is complicated by other environmental factors such as burial and insect invasion. Given the relative successes, however,

174 Birken and Cooper 2006:1107
175 Whitcraft 2007
176 Stokes and Smiley 1968
177 Cooper et al 2003; Friedman 2005; Birken and Cooper 2006
178 Mortenson et al. 2012
179 Mortenson et al 2012:1066
180 Hultine et al. 2013
181 Celma 2011; Tavares et al. 2014
tamarix growing in Egypt should be analyzed to determine their viability for dendrochronology, especially given their potential for elucidating local environmental information.

ACACIA (see Appendix E)

Derived from the Greek word for thorn (ακαία), acacia\(^{182}\) refers to a genus of spiny shrubs and trees distributed across Australia, Europe, Southern Asia, the Americas and Africa. Species of Acacia spp., like tamarix, are virtually indistinguishable by their wood structure alone.\(^{183}\) More than a dozen species are thought to be indigenous to Egypt, although only four merit consideration; the remainder are too rare or stunted to have been exploited in any significant way.\(^{184}\) Acacia raddiana and A. tortilis have a distribution that spans the entire country, A. nilotica appears in the Nile River Valley and A. albida is local to the area of Upper Egypt near Aswan.\(^{185}\)

Acacia trees are specifically adapted to desert ecosystems, able to survive intervals of flooding and drought by deploying deep root systems to capitalize on any available soil moisture when precipitation is scarce. Young plants frequently remain small until ample roots are established, at which point a favorable rainy season will initiate a surge in growth.\(^{186}\) Acacia trees range from 7 to 13 meters in height with multiple trunks measuring 20 to 30 cm in

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\(^{182}\) In 2005, the Acacia genus, composed of around 1300 species worldwide, was divided into five distinct genera grouped under the tribe Acaciæ. The majority of species occurring outside of Australia were reclassified in the new genera Vachellia and Senegalia. For a detailed discussion see Luckow et al 2003; Miller et al 2003; Maslin, Miller and Seigler 2003; Maslin, Orchard and West, 2003, Seigler and Ebinger 2005; Bouchenak-Khelladi et al., 2010; Miller & Seigler, 2012)
\(^{183}\) Western and McLeod 1995: 88
\(^{184}\) Hepper 1990:22; Western and McLeod 1995
\(^{185}\) Western and McLeod 1995
\(^{186}\) Springuel et al., 1995
diameter. They bear low, almost symmetrical crowns, with bipinnate leaves and sharp thorns. In dry seasons, *Acacia* spp., such as *A. albida*, may lose their leaves, although those *A. nilotica* residing in the Nile Valley may be almost evergreen. Among Bedouin groups in the eastern desert of Egypt, acacia trees are known to grow slowly, with traditional knowledge dating modern living stands back to “Roman” times, i.e. the pre-Islamic period. By radiocarbon dating living stands of *Acacia* spp. in the eastern desert, Andersen and Krzywinski were able to date individual trees back 650 years to the Mamluk period (c. AD 1350), with most sampled trees having germinated in the mid-16th century AD. Given the longevity of trees from Andersen and Krzywinski’s relatively small sample size, *Acacia* spp. in Egypt are expected to date between 200 and 700 years, perhaps longer.

Although frequently small and warped, the acacia tree represented an invaluable and plentiful resource. As noted by Western and McLeod, “apart from the advantage of easy availability, the wood of acacia can be of fine quality, being hard, durable, resistant to splitting and capable of taking a good smooth finish.” According to ancient sources from Egypt and surrounding regions, including tomb paintings, the Sixth-Dynasty inscription of Weni from Abydos, Herodotus, Theophrastes, and Pliny, acacia was the preferential timber for boat building in Egypt. In addition to boat construction, acacia was utilized for statues, furniture, bows, arrows, tools and construction elements such as dowels and other joinery (see Table 5, Appendix E).

187 Andersen and Krzywinski 2007  
188 Andersen and Krzywinski 2007  
189 Western and McLeod 1995:88  
190 Herodotus II:96  
191 Theophrastes IV:2  
192 Pliny Natural History XIII:19  
193 References to acacia in Egyptian texts specifically refer to its use in the construction of boats, including: “tow boats, [canal (?)] boats, boats for the transportation of cattle, warships and kara boats” (Breasted 1906 v.4:229).  
194 Hepper 1990:23; Western and McLeod 1995:89; Gale et al. 2000: 336
Wood Anatomy\(^{195}\)

Acacia timber is reddish, hard and durable. The wood is diffuse-porous with vessels existing in multiple, mostly short (2 to 3 vessels) radial rows. Axial parenchyma are present in marginal bands, as are diffuse apotracheal and paratracheal parenchyma. Prismatic crystals are observable in chambered axial parenchyma cells. Growth ring boundaries are generally visible and marked by fine marginal parenchyma containing small crystals of calcium oxalate.\(^{196}\)

Figure 16: Archaeological specimen of *Acacia* spp. recovered from excavation in Egypt (© 2006 WSL - F. Schweingruber, W. Landolt)

Marginal parenchyma refers to a type of axial parenchyma (a network of cells designed for transportation of sugars and storage of starch) that occurs in some species in bands located at the start or termination of a growth season.\(^{197}\) Comprised of five or fewer rows of

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\(^{195}\) See Robbertse 1980; Jagiella and Kürschner 1987; Gourlay 1995b
\(^{196}\) Cartwright and Taylor 2008
\(^{197}\) Gourlay 1995b:123
parenchymatous cells, marginal parenchyma forms a continuous layer around the tree that manifests visually as a fine, light-colored band. *Acacia* spp. exhibit multiple types of parenchyma, including apotracheal and paratracheal bands. The former exists independent of vessels while the latter forms around vessels. In *Acacia* spp., these bands exist in broad, irregular swaths, difficult to delineate, that may obscure the detection of the more delicate marginal parenchyma bands. Although in rare cases, variations in paratracheal bands may alternatively produce a pattern at the growth-ring boundary in *Acacia* spp. that could potentially aid in the identification of growth-ring zones. Small rhomboidal crystal chains were observed, concentrated along the axial parenchyma or its periphery. According to Gourlay, in the absence of clear marginal bands, it was still possible, albeit laborious, to date a sample by instead producing radial sections of the complete radius and individually counting the crystal chains.

**Literature Review**

Among the pioneers for establishing a comprehensive dendrochronological assessment of African *Acacia* spp. was Ian Gourlay, who, following exploratory work on acacia in Somalia, surveyed 15 distinct acacia species from an area spanning 14 degrees of latitude and six countries: Kenya, Malawi, Somalia, Zimbabwe, South Africa and Zambia. According to Gourlay, periodicity was determinable in many examined specimens, although the dense and complex character of the wood renders the task of dating difficult and subject to certain limiting factors. The presence of marginal parenchyma bands ultimately provided the best key to identifying annual growth, distinguishable from the relatively frequent intraseasonal banded

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198 Gourlay 1995b:123
199 Gourlay 1995b:128
200 Gourlay 1995b:128
201 Gammadid 1989
parenchyma by their fineness, evenness of appearance and irregular spacing between the broader bands.\textsuperscript{203} The bands, in confluence with the crystalliferous chains with which they were associated, were determined to indicate seasonal growth patterns in the acacia species examined.\textsuperscript{204} Gourlay\textsuperscript{205} found that observed rings were usually annual, with ring width dependant upon precipitation and/or minimum temperature.

The dating process heavily favored the need to collect whole stem disks rather than increment cores (which will prove problematic archaeologically). When attempted, the collection of increment cores presented challenges owing to the high density of acacia wood (more than 1.0g/cm\textsuperscript{3}). It was determined to be “not unusual” for the tempered steel borer to break during attempted sample collection as a result of excessive torque.\textsuperscript{206} In these situations, it was all the more easy for the operator to miss or fail to reach the pith\textsuperscript{207} with the borer. The extreme density of acacia, along with the rampant presence of gum and complexity of its anatomy, also prohibited the effective use of x-ray density measurements to aid in the identification of annual growth ring boundaries.\textsuperscript{208}

Similar difficulties were described by Wils,\textsuperscript{209} who in a summary of recent research on African acacia reported that, in most studies, collected cores did not represent viable options for dating and had to be discarded.\textsuperscript{210} In these samples, tree rings could not be identified or crossdated, due to “potentially missing rings, deviating responses to environmental factors and, 

\begin{footnotes}
\footnotemark[203] Gourlay 1995a:355 \\
\footnotemark[204] Gourlay 1995a:355 \\
\footnotemark[205] Gourlay 1995a \\
\footnotemark[206] Gourlay 1995a:354 \\
\footnotemark[207] Indicative of the earliest tree growth, a complete core that extends from the outer bark to the pith ensures that every recorded growth season is observable in the sample. A researcher must blindly estimate the general location of the small central pith when attempting to collect a sample, and if missed, the unaccounted for growth between the end of the sample and the pith (initiation of growth) must be calculated, an unreliable endeavor when periodicity is not well established. \\
\footnotemark[208] Gourlay 1995; Eshete and Ståhl 1999 \\
\footnotemark[209] Wils 2011 \\
\footnotemark[210] According to Wils (2011): 87\% of samples collected by Eshete and Ståhl (1999) were necessarily discarded and 20\% by Gebrekirstos et al. (2008).
\end{footnotes}
particularly, human disturbance.**211 Ultimately, human disturbance (e.g., over grazing of young acacia) represented one of the most significant detriments to the formation of datable wood conditions.212 Samples where that variable was absent proved to crossdate more frequently and more easily.213 Species of African acacia have also been shown to evince a strong correlation between ring formation and climate, as pointer years (highly recognizable and widely recorded patterns in growth rings indicative of responses to major regional climatic events) strongly corresponded to reported droughts and the periodic cycle of El Niño years (Wils 2011:348).

Nicolini et al. (2010) carried out research on acacia within the Western Sahel area of sub-Saharan Africa, in Niger. Anatomical studies demonstrated that identification of ring boundaries was feasible using the presence of marginal parenchyma bands, and associated calcium oxalate crystals. The authors were thus able to further educe the relationships between wood growth and the seasonal climatic trends of the area in order to determine the prevailing climate signal.214 Ring widths were measured along two radii of each collected stem disk, which were subsequently crossdated against each other, first visually and then verified through the statistical program COFECHA215 in order to identify potential missing or false rings. While frequently present, false bands and missing or partial rings were easily identified.216 A comparison of derived curves found that synchronization between multiple sites was possible, and the authors concluded that in the Sahel, *Acacia seyal* does form annual rings and reflects a strong climate signal based on precipitation.217

211 Wils 2011:347  
212 Gebrekirstos et al. 2008  
213 Wils 2011:347  
214 Nicolini et al. 2010:355  
215 see Cook and Homes 1999  
216 Nicolini et al. 2010:357  
217 Nicolini et al. 2010:358
Maingi\textsuperscript{218} surveyed the potential utility of 19 tree species, including acacia, from the Tana riverine forests in Kenya. Based on criteria that included the distinctiveness of growth rings, circuit uniformity, ring wedging and variability of ring widths, the study determined that five of the surveyed species were dendrochronologically viable, two of which were species of acacia (\textit{Acacia eliator} and \textit{Acacia robusta}).\textsuperscript{219} Growth rings were readily identified and counted, no ring wedging was observed and ring width variability was indicative that the trees were sensitive to some (unidentified) environmental factor.\textsuperscript{220} Despite this, crossdating was not deemed possible due in part to the fact that samples were of unknown cutting dates and were sourced from a variety of geomorphic sites. While the specific limiting factor for ring formation was not known, it was posited that, given the aridity of the region and consequential dependence of the trees on ground water, drought conditions during the low river flow months were responsible.

Eshete and Ståhl\textsuperscript{221} assessed the growth periodicity in acacia growing in the Rift Valley of Ethiopia. Their research demonstrated that acacia growing in dry and well-drained parts of the study area did generate an average of one annual ring per rainy season.\textsuperscript{222} The experience of the authors underscores the preferential use of whole stem disks rather than increment cores for the process of dating acacia.

Of most direct consequence to the assessment of the potential dendrochronological utility of native Egyptian \textit{Acacia} spp. is a study performed by Andersen and Krzywinski\textsuperscript{223}. In this study, they sought to examine the age and growth conditions of \textit{Acacia tortilis} in the hyper arid

\textsuperscript{218} Maigi 2006:181
\textsuperscript{219} Maingi 2006:182
\textsuperscript{220} Maingi 2006:191
\textsuperscript{221} Eshete and Ståhl 1999
\textsuperscript{222} Eshete and Ståhl 1999:116
\textsuperscript{223} Andersen and Krzywinski 2007
Eastern Desert of Egypt using a combination of radiocarbon dating and dendrochronological investigation. In examined specimens, *Acacia tortilis* exhibited marginal parenchymal bands with crystalliferous calcium oxalate chains formed coincidentally with temporary pauses in growth. In the specimens analyzed, however, the parenchymal bands were not found to exhibit any regular formation pattern. Correlation between band patterns among trees was determined to be poor, rendering the probability for crossdating marginal. Several factors may have contributed to the limited success of this study. Out of respect for local arboreal management traditions and sensitivity to the declining *A. tortilis* population, destructive sampling techniques were avoided. Only cores were taken, with drill-mounted steel corers developed to withstand the high torque inherent to the dense wood. Because of this, the majority of the samples did not include the pith, and extrapolation of its estimated location was made difficult because of heartwood rot and asymmetric growth. At the time of publication, no distinct climate signal was determined, although the authors were optimistic about the possibility that further research could elucidate insight into environmental factors affecting tree growth and past management.

**Chapter V: Conclusions**

Of the three most archaeologically abundant native species for ancient Egypt, acacia tentatively appears to demonstrate the highest dendrochronological viability. The longevity of individual trees (recorded as much as 650 years in one study) would facilitate the formation of an acacia chronology. A few intact and favorable specimens could span thousands of years of history (as opposed to with shorter lived trees, which would require multiple overlapping

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224 Andersen and Krzywinski 2007:5
225 Andersen and Krzywinski 2007:6
226 Andersen and Krzywinski 2007:6
227 Andersen and Krzywinski 2007:4
228 Andersen and Krzywinski 2007
specimens to cover the same time span as one long-lived acacia), and modern living trees could be connected back to at least the Mamluk period (c. AD 1350). Identification of growth rings is generally reliable and surveyed species seem to reflect annual periodicity in ring growth, although effective crossdating is an area that requires more testing. Of concern is the decline in efficacy when sampling of whole stem disks is not possible. The conditions experienced by Andersen and Krzywinski\textsuperscript{229} are a far more indicative representation of what may be expected of Egyptian acacia from archaeological contexts. The sampling of entire stem disks will likely be quite rare, with most samples being cores that often do not include the pith. Additionally, any samples obtained would need to demonstrate a minimum number of rings for confident crossdating, the specific amount to be determined over the course analysis and trial dating.

Recent concerns raised over the viability of native Egyptian acacia cite as evidence personal experiences and anecdotal references to an unsuccessful dating attempt by Douglass and his students of one sample of acacia acquired from the Meidum pyramid in the 1930s.\textsuperscript{230} While of obvious concern, it is likewise true that, in Douglass’ time, acacia (as with many other challenging species) was believed undatable. It is only in the past 20 years that acacia and tamarisk have been successfully utilized in dendrochronology anywhere. As a consequence, more favorable contemporary studies reflecting advances in ring identification have been given more weight in the assessment of dendrochronological potential discussed above. Kuniholm\textsuperscript{231} states that he has previously analyzed more than 1000 samples of acacia and was entirely unable to identify rings. With no discussion or publication of these tests, it is unclear whether these samples were sourced from Egyptian contexts or elsewhere. It is entirely possible that acacia, and indeed no native species of tree from Egypt will date, despite successes with these species in

\textsuperscript{229} Andersen and Krzywinski 2007
\textsuperscript{230} Kuniholm 2014:S95
\textsuperscript{231} Kuniholm 2014:S94
other arid regions. Without definitive trials and publication of results, however, the state of dendrochronology in Egypt will remain ambiguous. It is paramount that more in depth research and sampling be undertaken for native Egyptian species.

Overall, the potential viability for two of the three most commonly exploited native species of ancient Egyptian wood offers enough promise to advance the investigation of tree-ring studies in Egypt. Next steps necessarily involve the thorough sampling and analysis of living trees in Egypt as proof of concept (to be undertaken in 2015). Further pursuit of dendrochronological endeavors in Egypt, exploring both native and imported species of wood, will require the establishment of in-country facilities to take advantage of the wealth of wooden material that cannot be exported for analysis due to legal restrictions. The relative ease and minimal cost with which dendrochronological studies can be undertaken makes it a particularly attractive technique for development in Egypt, especially compared to other scientific dating methods such as radiocarbon. At its most basic level, dendrochronology can be performed with a microscope, pencil and graph paper, yielding unfailingly accurate and precise results with no margin of error. Professionals may be easily trained to collect and evaluate samples so that a sufficient volume of material for effective study may be procured and processed. Germinating an interest and appreciation for a dendrochronology of ancient Egypt, both within the modern country and abroad, will be paramount to for the growth of tree-ring studies, and must begin with an elucidation of the impediments and opportunity presented by the Egyptian context.

The history of ancient Egypt is defined by millennia of intensive wood use, the legacy of which can be seen in an archaeological record that is replete with wooden artifacts that have preserved extremely well in the arid environment. For a country that has thus far received scant attention in this field, Egypt is uniquely positioned to benefit from the application of
dendrochronological and dendroarchaeological research, having both a great need and great promise.
APPENDIX A

CHRONOLOGY OF EGYPT FROM THE PREDYNASTIC PERIOD TO THE PRESENT

<table>
<thead>
<tr>
<th>Period</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predynastic Egypt</td>
<td>Pre-c.3100 BC</td>
</tr>
<tr>
<td>Early Dynastic (Dynasties 0-2)</td>
<td>c. 3100-2686 BC</td>
</tr>
<tr>
<td>Old Kingdom (Dynasties 3-6)</td>
<td>c. 2686-2181 BC</td>
</tr>
<tr>
<td>1st Intermediate Period (Dynasties 7-11)</td>
<td>c. 2181-2055 BC</td>
</tr>
<tr>
<td>Middle Kingdom (Dynasties 11-13)</td>
<td>c. 2055-1650 BC</td>
</tr>
<tr>
<td>2nd Intermediate Period (Dynasties 13-17)</td>
<td>c. 1650-1550 BC</td>
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<tr>
<td>New Kingdom (Dynasties 18-20)</td>
<td>c. 1550-1069 BC</td>
</tr>
<tr>
<td>3rd Intermediate Period (Dynasties 21-25)</td>
<td>c. 1069-664 BC</td>
</tr>
<tr>
<td>Late Period (Dynasties 26)</td>
<td>c. 664-332 BC</td>
</tr>
<tr>
<td>Achaemenid Egypt</td>
<td>c. 525-332 BC</td>
</tr>
<tr>
<td><strong>Classical Antiquity</strong></td>
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</tr>
<tr>
<td>Ptolemaic Egypt</td>
<td>332-30 BC</td>
</tr>
<tr>
<td>Roman and Byzantine Egypt</td>
<td>30 BC-AD 641</td>
</tr>
<tr>
<td>Sessanid Egypt</td>
<td>AD 621-629</td>
</tr>
<tr>
<td><strong>Middle Ages</strong></td>
<td></td>
</tr>
<tr>
<td>Arab Egypt</td>
<td>AD 641-969</td>
</tr>
<tr>
<td>Fatimid Egypt</td>
<td>AD 969-1171</td>
</tr>
<tr>
<td>Ayyubid Egypt</td>
<td>AD 1171-1250</td>
</tr>
<tr>
<td>Mamluk Egypt</td>
<td>AD 1250-1517</td>
</tr>
<tr>
<td><strong>Early Modern</strong></td>
<td></td>
</tr>
<tr>
<td>Ottoman Egypt</td>
<td>AD 1517-1867</td>
</tr>
<tr>
<td>French Occupation</td>
<td>AD 1798-1801</td>
</tr>
<tr>
<td>Egypt under Mohammed Ali</td>
<td>AD 1805-1882</td>
</tr>
<tr>
<td>Khedivate of Egypt</td>
<td>AD 1867-1914</td>
</tr>
<tr>
<td><strong>Modern Egypt</strong></td>
<td></td>
</tr>
<tr>
<td>British Occupation</td>
<td>AD 1882-1922</td>
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<tr>
<td>Sultanate of Egypt</td>
<td>AD 1914-1922</td>
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<tr>
<td>Kingdom of Egypt</td>
<td>AD 1922-1953</td>
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<tr>
<td>Republic</td>
<td>AD 1953-Present</td>
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APPENDIX B

EVALUATION OF THE DENDROCHRONOLOGICAL POTENTIAL OF COMMON NATIVE EGYPTIAN TREE SPECIES

A qualitative evaluation of the potential utility of native Egyptian tree species based on a review of published literature. Viability is determined by the presence of favorable anatomical features and the reported success of previous dendrochronological studies of these species in comparable (arid) climates.

Table 2

<table>
<thead>
<tr>
<th>Wood Type</th>
<th>Distinctness of Ring Boundary</th>
<th>Circuit Uniformity</th>
<th>Ring Wedging</th>
<th>Ring Width Variability</th>
<th>Potential for usefulness for dendrochronology</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ficus sycomorus</em></td>
<td>FAIR*</td>
<td>FAIR*</td>
<td>FREQUENT*</td>
<td>MODERATE*</td>
<td>POOR*</td>
</tr>
<tr>
<td><em>Tamarix sp.</em></td>
<td>GOOD†</td>
<td>GOOD†</td>
<td>MODERATE†</td>
<td>MODERATE†</td>
<td>GOOD†</td>
</tr>
<tr>
<td><em>Acacia sp.</em></td>
<td>GOOD*</td>
<td>GOOD*</td>
<td>NONE*</td>
<td>MODERATE*</td>
<td>GOOD*</td>
</tr>
</tbody>
</table>

(adapted from Maingi 2006, Table 3)

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232 *Maingi 2006; †inferred from Birken and Cooper 2006; Cooper et al. 2003; Friedman 2005; Hereford 1984; Mortenson et al. 2012; Whitcraft et al. 2007.
## APPENDIX C

### Table 3

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Taxon</th>
<th>Species in Egypt</th>
<th>Wood Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sycomore Fig</td>
<td>Moraceae</td>
<td>Ficus Sycomorus</td>
<td>Dicotyledonous Hardwood</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selection of Sycamore Artifacts from Ancient Egypt (Gale et al. 2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predynastic Period:</td>
</tr>
<tr>
<td>Roots</td>
</tr>
<tr>
<td><strong>VIIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Dummy Vases</td>
</tr>
<tr>
<td>Column Base</td>
</tr>
<tr>
<td><strong>VIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>Late Old Kingdom:</strong></td>
</tr>
<tr>
<td>Coffins</td>
</tr>
<tr>
<td><strong>VIIth Dynasty:</strong></td>
</tr>
<tr>
<td>1st Intermediate Period:</td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td>1st Intermediate Period:</td>
</tr>
<tr>
<td>Coffin Fragment</td>
</tr>
<tr>
<td>Dowels</td>
</tr>
<tr>
<td><strong>c. Middle Kingdom:</strong></td>
</tr>
<tr>
<td>Numerous coffins</td>
</tr>
<tr>
<td><strong>XVIIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Roots</td>
</tr>
<tr>
<td><strong>Early XVIIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffins</td>
</tr>
<tr>
<td><strong>Late XIXth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>Early XIXth Dynasty:</strong></td>
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<tr>
<td><strong>Late XXth Dynasty:</strong></td>
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<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXIIIrd Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXIVth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXVth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXVIth Dynasty:</strong></td>
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<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXVIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXVIIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
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<tr>
<td><strong>XXIXth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXXth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>c. New Kingdom:</strong></td>
</tr>
<tr>
<td>Miniature Coffins</td>
</tr>
<tr>
<td><strong>IIIrd Intermediate Period:</strong></td>
</tr>
<tr>
<td>Stela</td>
</tr>
<tr>
<td><strong>XXIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXIIIrd Dynasty:</strong></td>
</tr>
<tr>
<td>Stela</td>
</tr>
<tr>
<td><strong>XXIVth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXVth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXVIth Dynasty:</strong></td>
</tr>
<tr>
<td>Stela</td>
</tr>
<tr>
<td><strong>XXVIIth Dynasty:</strong></td>
</tr>
<tr>
<td>Coffin</td>
</tr>
<tr>
<td><strong>XXVIIIth Dynasty:</strong></td>
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<td>Coffin</td>
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<td><strong>XXIXth Dynasty:</strong></td>
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<tr>
<td><strong>XXXth Dynasty:</strong></td>
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<td>Coffin</td>
</tr>
<tr>
<td><strong>Prolemaic Period:</strong></td>
</tr>
<tr>
<td>Wagon</td>
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<tr>
<td><strong>Prolemaic/Roman Period:</strong></td>
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<tr>
<td>Numerous Stelae</td>
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</table>

(Georg Ebers, 1878)
## APPENDIX D

Table 4

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Selection of Tamarisk Artifacts from Ancient Egypt (Lucas and Harris 1962)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tamarisk</td>
<td>Late Quaternary Stems and branches</td>
</tr>
<tr>
<td>Taxon Tamaricaceae</td>
<td>XVIIth Dynasty Box Lid Foot of Pall Support Throw Stick</td>
</tr>
<tr>
<td>Species in Egypt</td>
<td>Neolithic Twigs Worked Sticks</td>
</tr>
<tr>
<td>Tamarix aphylla, T. nilotica T. tetragyna, T. amplexicaulis T. passerinoides, and T. macrocarpa</td>
<td>New Kingdom Twig</td>
</tr>
<tr>
<td>Wood Type</td>
<td>Predynastic Roots and Twigs</td>
</tr>
<tr>
<td>Dicotyledonous Hardwood</td>
<td>Roman Period Coffin Coffin Pegs</td>
</tr>
<tr>
<td></td>
<td>Ist-IIIrd Dynasty Charcoal</td>
</tr>
<tr>
<td></td>
<td>XXth-XXVIth Dynasty Coffin Pegs</td>
</tr>
<tr>
<td></td>
<td>XIth Dynasty Roots</td>
</tr>
<tr>
<td></td>
<td>Roman Period Fragments</td>
</tr>
<tr>
<td></td>
<td>c. Middle Kingdom Walking Stick</td>
</tr>
<tr>
<td></td>
<td>IVth Century AD Wood Fragments</td>
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</tbody>
</table>
# Appendix E

Table 5

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Selection of Acacia Artifacts from Ancient Egypt (Gale et al. 2000)</th>
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</thead>
<tbody>
<tr>
<td><strong>Predynastic Period:</strong></td>
<td>Predynastic-1st Dynasty:</td>
</tr>
<tr>
<td>Log</td>
<td>Coffin</td>
</tr>
<tr>
<td>Roots</td>
<td>Roof Beams</td>
</tr>
<tr>
<td>Chisel Handle</td>
<td>Arrow Fragments</td>
</tr>
<tr>
<td>Shrine</td>
<td>1st Dynasty:</td>
</tr>
<tr>
<td>Coffin</td>
<td>Charcoal</td>
</tr>
<tr>
<td><strong>Predynastic-1st Dynasty:</strong></td>
<td>I-IIIrd Dynasty:</td>
</tr>
<tr>
<td>Coffin</td>
<td>Trunks and Branches</td>
</tr>
<tr>
<td>Roof Beams</td>
<td>6th-XIIth Dynasty:</td>
</tr>
<tr>
<td>Arrow Fragments</td>
<td>Coffin Peg</td>
</tr>
<tr>
<td>1st Dynasty:</td>
<td>Bow Fragments</td>
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<tr>
<td>Charcoal</td>
<td>Arrow Fragments</td>
</tr>
<tr>
<td>I-IIIrd Dynasty:</td>
<td>IXth-XIth Dynasty:</td>
</tr>
<tr>
<td>Trunks and Branches</td>
<td>Bow</td>
</tr>
<tr>
<td>6th-XIIth Dynasty:</td>
<td>Headrest</td>
</tr>
<tr>
<td>Coffin Peg</td>
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<td>Bow Fragments</td>
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<td>Arrow Fragments</td>
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<tr>
<td>IXth-XIth Dynasty:</td>
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</tr>
<tr>
<td>Bow</td>
<td></td>
</tr>
<tr>
<td>Headrest</td>
<td></td>
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<tr>
<td><strong>XIIth Dynasty:</strong></td>
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<tr>
<td>Sarcophagus Dowels</td>
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<td>Coffin Dowels</td>
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<td>Box Dowels</td>
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<td>Knobs</td>
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<td>Stool</td>
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<td><strong>Second Intermediate Period:</strong></td>
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<td><strong>XVIIth-XVIIIth Dynasty:</strong></td>
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<td>Arrow Fragment</td>
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<td><strong>XVIIIth Dynasty:</strong></td>
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<td>Part of Body of Chariot</td>
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<td>Pegs</td>
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<td>Dowel</td>
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<td><strong>c. New Kingdom:</strong></td>
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<td>Bolt</td>
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<td>Bow</td>
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<td>Arrows</td>
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<tr>
<td><strong>1st Century BC:</strong></td>
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<tr>
<td>Boning Rod</td>
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(John Douglas Woodward, 1881)
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Chamberlin, Pierre  

Cichocki, Otto  

Cichocki, Otto  

Cichocki, Otto  
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