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## Original article

Dating and provenancing the *Woman with lantern* sculpture – A contribution towards attribution of Netherlandish art

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## ABSTRACT

Studying the wood of art objects such as sculptures, panel paintings and furniture can be crucial to elucidate their chronology and production centre. Here we present an approach that considers the provenance of the wood and its potential availability in different areas as a means to identify the provenance of wooden art objects. We illustrate this approach with an interdisciplinary study aimed to determine the date and provenance of the *Woman with lantern*, a carved altar fragment from the Rijksmuseum's collections (Amsterdam, The Netherlands). The origin of this object is undocumented, but based on stylistic and iconographic features its provenance was proposed to be the altarpiece of Rennes cathedral (France), carved in Antwerp (Belgium) around 1520 C.E.. However, doubts arose when curators tested the potential fit of the sculpture in that altarpiece and could not find a neat match. Dating and provenancing the wood of the sculpture by standard dendrochronological means failed to produce a date, and comparison of the tree-ring pattern from the sculpture with those of the sculptures from Rennes altarpiece delivered no results either, supporting the suspicion that the *Woman with lantern* belonged elsewhere. In 2019, X-ray computed tomography (CT) provided digital cross-sections throughout the sculpture and a longer tree-ring series was obtained. This time, the outermost ring was dated to the year 1487 C.E.. The tree was estimated to have been cut after 1495 C.E., indicating a likely production in the first quarter of the 16th century. The origin of the timber in the eastern Netherlands/northwest Germany, combined with empirical evidence about timber availability in various regions of the Low Countries at that time, suggests that the sculpture was made in a workshop located north of the Rhine in the (current) Netherlands, rather than Antwerp. This research has led to the hypothesis that workshops north and south of the Rhine river branches in the Low Countries were supplied by forests located in different areas. If proven correct, establishing the wood provenance will assist in determining the origin of Netherlandish works of art from the late-Gothic and Northern Renaissance periods.

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## 1. Introduction

## 1.1. Late Gothic carved altarpieces from the Low Countries

Small-scale wooden sculptures are often exhibited at museums as independent works of art, while many of them are in fact fragments that originally belonged to late-Gothic carved altarpieces

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**Figure 1.** Sculpture and its historical context. a) *Woman with lantern* (source: Rijksmuseum, <http://hdl.handle.net/10934/RM0001.COLLECT.24420>); b) Low Countries around the mid-16th century. The Duchy of Brabant has been outlined and relevant cities mentioned in the text have been plotted. [1.5-column fitting image; colour]

(retables). In the Low Countries, the production of these wooden carved altarpieces flourished from the 1380s up to the 1550s, but countless of them were destroyed during the iconoclasm outbreak of 1566 [1,2]. Others were dismantled, or simply have not survived intact. The remaining sculptures and painted wings were subsequently dispersed. Only in rare cases has it been possible to convincingly link certain separated fragments with one another or with an extant altarpiece. Such is the case, for example, of at least seven sculpted groups and fragments which have been found to originate from the Marian altarpiece made by the Utrecht sculptor Adriaen van Wesel for the Confraternity of Our Lady in Den Bosch in 1475-77 [3].

Attributions of individual carved altar fragments to specific masters, workshops, cities or regions are usually made through observation of their stylistic features, iconography, production techniques, and comparison with other sculptures in altarpieces for which the commission and provenance history is known through archival documentation, travel notes and the like [4,5]. Furthermore, sculptures made in the Brabantine cities of Antwerp, Brussels and Mechelen are often stamped or branded with a wood quality control mark of the local guild: the 'Antwerp hand', the 'Brussels mallet' or 'the three pales of Mechelen' [1], which serve to determine the place of origin and sometimes also a *post quem* date for the object [6]. Few works bear a sculptor's signature, as is the case of an altar fragment by the Leuven woodcarver Hendrik Roesen recently acquired by the Museum M in Leuven (museum inv. no. C/716-b; [7]). However, when clues like these are lacking, the precise production centre within the Low Countries remains undetermined.

## 1.2. The Woman with the Lantern sculpture: where does it come from?

The *Woman with lantern* (WWL) is a small-scale sculpture carved from a single piece of deciduous oak wood (*Quercus* subsp. *Quercus*) that also derives from an altarpiece, as implied by her small dimensions (height 35.8cm × width 12.4cm × depth 5.8cm), the sloped integrally carved ground on which she stands, and the nail holes at the base (Fig. 1a). However, no information exists as to which altarpiece this was, or where it was produced. The sculpture's style, iconography and the way she is carved as an individual figure (instead of being an integral part of the altar group) suggest a Brabantine origin (see 3.1). In the Low Countries (Fig. 1b), the Brabantine cities of Antwerp, Brussels and, to a lesser extent, Mechelen, dominated the market for carved altar pieces from the end of the 15th to the first half of the 16th century [8]. About 350 carved altarpieces from the southern Netherlands (including Brabant) still exist throughout the world [1]. Although only a fraction of their original number, this is quite a lot, especially considering the scarce examples that remain from the Northern Netherlands [8].

In 2017, art-historian Guillot de Suduiraut proposed that the WWL might be one of the missing figures from the exquisitely carved and polychromed altarpiece of Rennes cathedral (France), which is dedicated to the Life of the Virgin [9] (Fig. 2a). This altarpiece was made in Antwerp, as is clearly attested by its style, as well as the presence of no less than thirty-four 'Antwerp hands'. Its inverted 'T'-shaped shrine consists of two tiers with three compartments each, and stands on a predella equally divided into three





**Figure 2.** The WWL in the context of the Rennes altarpiece; a) Rennes (France), Cathedral Treasure room, altarpiece with scenes from the life of the Virgin (Antwerp, c. 1520); frames have been drawn to indicate the scene depicted in b, and the sculpture shown in c (photo: cliché Jérôme Mongreville © Région Bourgogne-Franche-Comté, ADAGP, 2018); b) WWL placed in the Nativity scene ; c) WWL compared with another sculpture from the altarpiece showing obvious differences in dimension (photos b, c courtesy of Frits Scholten). [1.5-column fitting image; colour]

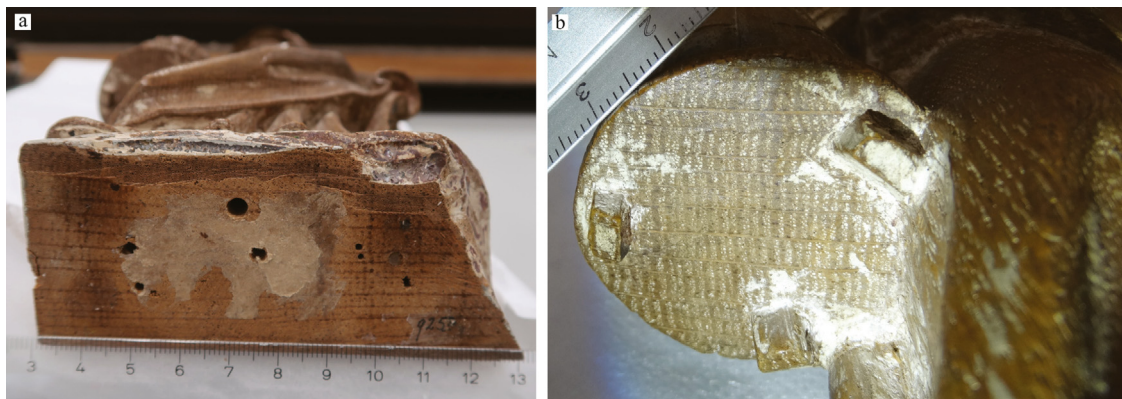
compartments. The painted wings of the altarpiece and several carvings from its interior are missing. In addition to the stylistic similarities, the woman's befitting pose with her head turned left, as well as the matching iconography, led Guillot de Suduiraut to suggest that the WWL might derive from the empty spot at the right of the Nativity scene in this altar, where she would face the remaining figures (Fig. 2b). The figure originally occupying this spot had been missing since at least 1857, as can be inferred from a photograph taken in that year. However, doubts arose when the WWL sculpture was taken to Rennes in May 2017 and was physically placed into the altarpiece. Compared to the other figures, its scale was too small (Fig. 2c), and the ground on which she stands was sloped too steeply. Furthermore, the sculpture's carving was in some areas more refined than that of the main figures in this scene, which is unusual for a figure of secondary importance to the depicted narrative [9].

### 1.3. A first attempt to date and provenance the sculpture by dendrochronology

An attempt to date the sculpture by dendrochronology and establish whether the wood originated from the same area as the other sculptures from Rennes altarpiece was also made in 2017. Dendrochronology (i.e. tree-ring research) is commonly used to determine the date and provenance of the wood used in historical objects and structures (see e.g. [10–14]). This scientific technique provides an absolute date for each ring on a piece of wood, and when the outermost tree ring (i.e. the most recent one located un-

der the bark) is present in the timber, the felling date can even be narrowed down to a couple of months (e.g. [15,16]). Furthermore, by comparing tree-ring patterns of contemporary wooden objects it is possible to identify wooden elements (e.g. planks of panel paintings, sculptures, timbers in buildings, etc.) that originated from the same tree, or clusters of timbers from the same forest or provenance (see for example, p. 174 in [17], p. 159 in [18]). Such findings inform about the economy and supply of timber resources at ateliers and construction sites, and may assist to attribute works of art to certain artists or workshops.

Dendrochronological research on sculptures is typically done at the underside/bottom, which usually represents the widest transverse section of the piece of wood and provides the highest number of tree rings [19–21]. In the WWL, pith and sapwood are absent. The underside has a flat surface, but to allow a crisp observation of the tree-ring boundaries it was necessary to clean slightly two thin strips of c. 8 mm wide with sharp scalpel blades (Fig. 3a). The underside of the lantern has a very smooth surface where the tree rings can be seen without cleaning (Fig. 3b). Therefore, it was photographed as well in order to gain additional tree rings towards the outer part of the tree. A series with 88 rings was obtained from the base of the sculpture, whereas the base of the lantern provided a series with 28 rings. Both parts overlapped 23 rings, and a series of 93 years was achieved. Crossdating with a set of oak reference chronologies from central and northern Europe failed to produce a date for the tree-ring series from the WWL [22]. Comparison of this tree-ring series with the ones obtained from the sculptures of Rennes altarpiece in another study conducted by Pascale Fraiture



**Figure 3.** Areas in the WWL where dendrochronological research was done with digital photographs; a) base of the sculpture where two shallow lines were cleaned in 2017 for tree-ring analysis; b) base of the lantern where additional tree rings were photographed and measured without prior preparation of the surface. [2-column fitting image; colour]

(KIK-IRPA, Brussels, Belgium) showed no matches that would indicate that it was made of wood from the Baltic area as the other sculptures (Fraiture, email comm. on 23 October 2017). This result was in accordance with the aforementioned stylistic discrepancies. Consequently, the hypothesis that the sculpture belonged to Rennes altarpiece was also refuted by the dendrochronological findings [9], and its exact production centre remained unknown.

## 2. Research aim

In 2019, a new attempt to establish the date and provenance of the sculpture by dendrochronology was conceived, this time using X-ray computed tomography (CT) imaging. CT imaging allows the 3D reconstruction of the inner structure of objects with different degrees of resolution (e.g. [23,24]). These 3D reconstructions can be virtually sliced through at any desired direction to observe the interior of the object. Unlike most sculptures, the widest part of the WWL is not found at the underside, but higher up, where the bottom of the lantern joins the body of the lady. This research was therefore aimed to obtain the longest possible tree-ring series from the sculpture in order to determine the date and provenance of the wood, and by inference deducing the construction period and place of manufacture. To this purpose, dendrochronological research was carried out on a combination of high-resolution X-ray CT images and digital photographs.

## 3. Material and Methods

### 3.1. The sculpture

The WWL was acquired by the Rijksmuseum from a private collector in 1890 (Rijksmuseum inventory number BK-NM-9253, <http://hdl.handle.net/10934/RM0001.COLLECT.24420>). Back then, the polychromy was already completely scraped off, and only some traces of chalk and paint remained. These traces indicate that most of the figure was originally gilded, with the exception of the face, hands, turban, the inside of the robe, the collar and the lantern [25]. A layer of green glaci was present over the gilding of the base. The seam of the robe was decorated with punched motifs, the imprints of which are still visible in the bare wood. No stamped or branded quality-control marks have been found in the surface.

The fact that the figure holds a lantern allows the depicted character to be identified as a midwife, or a Persian Sybille [26]. Similar lantern-carrying women, often also wearing a turban on

their head, can be found in several Antwerp altarpieces dedicated to the Infancy or Passion of Christ, or to the Life of the Virgin, in the context of scenes representing one of the earliest moments of Christ' life, i.e. either the Nativity or the Adoration of the Shepherds [27]. The sculpture is therefore very likely to originate from an altar dedicated to one of those themes.

### 3.2. Scanning the sculpture

The sculpture was scanned at the Flex-ray lab of the *Centrum Wiskunde en Informatica* (CWI) in Amsterdam following the dynamic process of imaging described by [28] Coban et al. (2020). This CT scanning facility consists of a cone-beam microfocus X-ray point source, projecting onto a flat-panel detector of  $1944 \times 1536$  pixels. It has the capacity to scan objects up to 45 cm tall. The sculpture was mounted on a wooden support and placed on the Flex-ray platform (Fig. 4a). For a CT scan the object is rotated  $360^\circ$ , and X-ray images are taken at known angular intervals. The statue was too tall to fit on the detector in one projection image. Therefore, it was scanned in parts, starting from the bottom of the sculpture and moving the source and the detector upwards to scan its full height. In total, five partial scans were necessary to fully capture the object, obtaining 2,915 images for each partial scan (one image every 0.12 degree). These five partial scans were performed with tube voltage 50kV, tube power 50W and a 2mm Al filter. The exposure time was 400ms per projection image and the object was scanned at a magnification of 1.1.

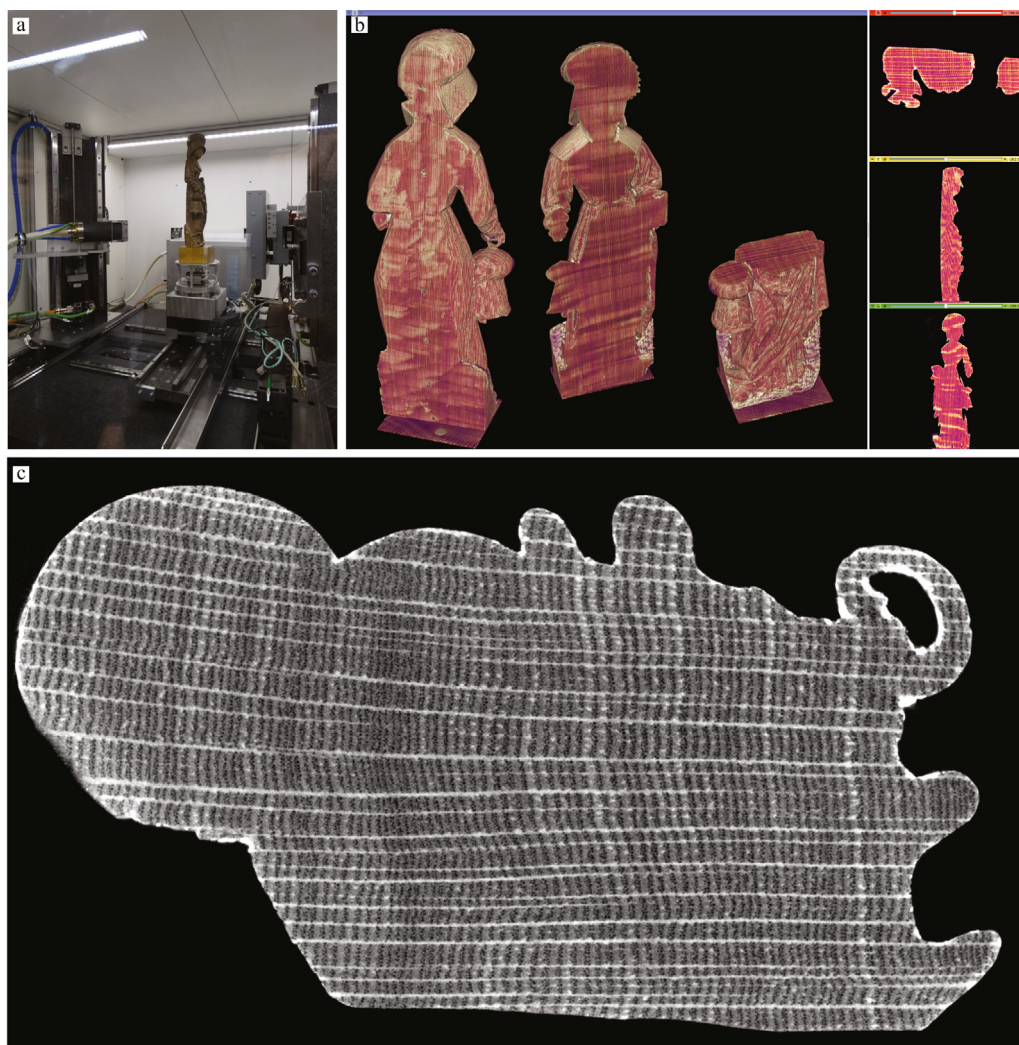
### 3.3. Producing the X-ray CT images

All the X-ray images were then combined using Flexbox software [29] to create a 3D reconstruction of the object. The full sculpture was reconstructed with a resolution of 135.6 micron, which enabled us to virtually 'cut' the object and look at the interior at different depth and orientation (Fig. 4b). A higher-resolution reconstruction was made of the area of interest, i.e. the cross-section corresponding to the height of the base of the lantern, where the sculpture reaches the widest section (Fig. 4c). This reconstruction achieved a resolution of 67.8 micron.

### 3.4. Tree-ring measuring and crossdating procedures

The base of the sculpture and the base of the lantern were thoroughly cleaned with a brush and photographed again using a 20.2-





**Figure 4.** Set up to scan the sculpture in the FleXray at the Centrum Wiskunde & Informatica in Amsterdam, The Netherlands. a) Sculpture mounted on the rotation stage of the scanner, with the X-ray source on the left and the detector on the right; b) Different sections of the CT reconstructed images of the sculpture; c) CT reconstructed cross-section of the sculpture at the height of the base of the lantern, where the longest tree-ring series was obtained (growth direction towards the left). [2-column fitting image; colour].

megapixel compact camera with an automatic macro-lens mode. As in 2017, a ruler was included in the photos to allow the calibration of the measurements, so that all measurements obtained represent absolute values. Tree-ring widths were measured as coordinates on these images and on the CT image of the cross-section at the height of the base of the lantern using Coorecorder (Cybis). The series of coordinates were converted to tree-ring width series in CDendro (Cybis), and PAST4 v. 4.3.1025 (SCIEM) was used to crossdate the tree-ring series with reference chronologies from central and northern Europe.

To identify the correct date we considered several tests that are automatically calculated in PAST4: Student's  $t$ -value after normalisation of the data as implemented by [30] (TBP); percentage of parallel variation (%PV) [31] and its associated significance level. The Student's  $t$ -value is based on the correlation coefficient ( $r$ ), and measures the probability that the similarity between two overlapping series happens by chance [32]. For series longer than 100 rings, TBP values above 6 are usually indicative of a matching position (i.e. a date). The %PV is a non-parametric test that can be used in combination with the TBP. It represents the synchronicity in the year-to-year variation between two overlapping series, hence it can be considered like a numerical representation of the visual match. For 100 years overlap, %PV above 65% become highly significant.

## 4. Results and discussion

### 4.1. Date and provenance of the wood

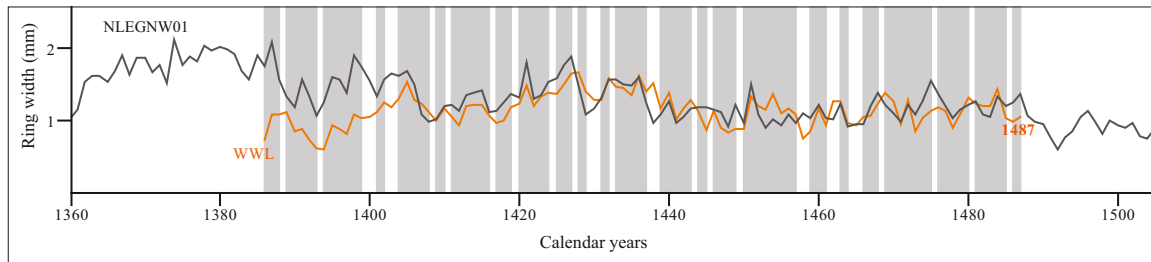
A combination of the measurements carried out on the new digital photographs and the high-resolution X-ray CT images obtained from the widest parts of the sculpture resulted in a tree-ring series with 102 years. Crossdating with the reference chronologies this time produced a date for the sculpture, with the outer (most recent) ring present in the lantern dating to 1487 C.E. (Table 1, Fig. 5). The tree-ring series obtained from the sculpture covers therefore the period 1386–1487 C.E..

The chronology providing the best match, NLEGNW01, is a chronology that is composed of 39 tree-ring series from archaeological wood and timber from historic buildings in Alkmaar (3 timbers), Amersfoort (3), Arnhem (1), Deventer (6), Dordrecht (1), Enkhuizen (1), Groningen (7), Haarlem (2), Hattem (1), Hoorn (1), Kampen (5), Leiden (5), Nibbixwoud (1), Tiel (1) and Winterswijk (1) [33] (Fig. 6). The majority of those timbers (probably all except the one from Winterswijk) had not been sourced locally when the construction of those structures took place, as forests in the vicinities of those cities were scarce by the late 15th century [39]. Most of those timbers have been dated with a chronology representing

**Table 1**

Crossdating results of WWL with reference chronologies for the outermost ring dated to 1487 (102 years overlap with all the chronologies). Only results of TBP>4 are shown; DateR, end date of the regional chronologies; *r*, correlation coefficient; TBP, Student's *t*-value as implemented by [30] for tree-ring studies; %PV, percentage parallel variation between the overlapping portion of the tree-ring series under investigation with the reference chronologies; SL, significance level of the %PV: #,  $p < 0.05$ , ##,  $p < 0.01$ , ###,  $p < 0.001$ .

Regional chronologies	DateR	<i>r</i>	TBP	%PV	SL	Suspected provenance	Reference
NLEGNW01	1592	0.58	7.19	70.1	###	E Netherlands/NW Germany	[33]
nlwf1040	1972	0.49	5.64	65.7	###	Twente (E NL)/Westphalia (NW Germany)	Tisje, unpublished
nlmidden	1666	0.45	4.96	68.6	###	Wood found in central and S Netherlands	[34]
Liège1	1614	0.42	4.38	63.2	##	Wood found in Liège	[35]
RM	1598	0.41	4.36	62.3	##	Rhine	[36]
Ofr18mMM	1992	0.42	4.32	59.3	#	NW Germany, E Friesland	[36]
WD4	1975	0.38	4.14	62.7	##	W Germany	[36]
zd631mmm	1950	0.37	4.09	63.2	##	S Germany	[37]
NBH1036M	1972	0.38	4.04	60.8	#	Wood imported in Netherland from Germany	[38]



**Figure 5.** Visual match between the tree-ring series obtained from the sculpture (WWL) and the reference chronology providing the best match (NLEGNW01). The grey background lines highlight the years in which the patterns of both curves variate synchronously. [2-column fitting image; colour]

the historical region of Twente in the east of the current Netherlands and the region of Münster, in the north of North Rhine-Westphalia state (Tisje, unpublished). This suggests that they were probably harvested in forests from those areas, and by inference, that the wood from the sculpture also originates from there.

#### 4.2. Timber supply in the Low Countries: the river systems and the Baltic trade

The limitations of using historical chronologies to pinpoint the origin of wood are well known (see [21] for an overview), but in regions such as the Low Countries, with a long history of deforestation and timber imports, it is the most cost-effective tool we currently have to infer the provenance of historic wood. In this geographical area, looking at the water systems, upper-river catchment areas, and the maritime timber-trade connections complements dendrochronological results obtained with historical chronologies, and becomes paramount to understand the flow of imported timber in different periods.

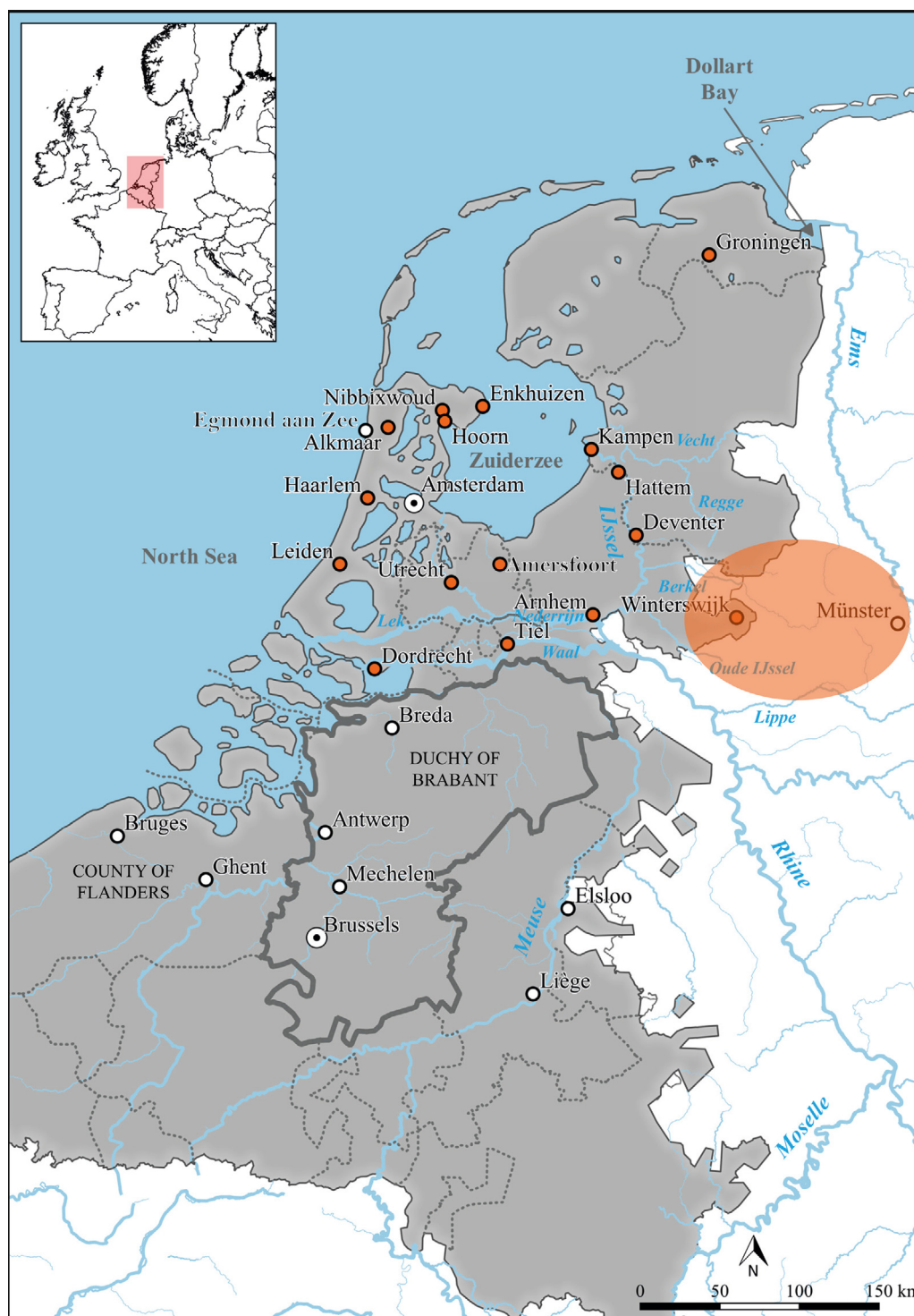
According to [40], wood from the region of Münster would reach the Rhine delta river system and the Zuiderzee through rivers such as the Lippe, Berkel, Vecht, Regge and Oude IJssel/Bocholter Aa (Fig. 6). The Lippe linked the woodlands in Münster with cities along the Rhine and its two branches, Waal and Nederrijn/Lek. Dordrecht, located along the Waal, had acquired staple rights in 1299 that included exclusivity of distribution of Rhine and Meuse imported timber [41]. In the 14th and early 15th centuries, timber was distributed from Dordrecht in an area covering from Egmond aan Zee, in the northwest of the current Netherlands, to Ghent, in current Belgium. The flood of 1421 struck the city of Dordrecht, and the staple rights became less effective, with other cities taking part on that distribution [42]. Arnhem is located along the Nederrijn, which becomes the Lek further down and connects with Utrecht and Vleuten through canals. The Berkel and Oude IJssel/Bocholter Aa provided waterways to transport the timber towards the IJssel, where Deventer and Kampen held staple rights for wood markets in the late 15th /early 16th centuries [43]. Such rights implied that timber-loaded ships sailing by had

to stop at those harbours, unload their cargo, and give local craftsmen and traders the opportunity to buy wood before continuing their route. As a result, timber from specific sources is more abundant in towns and villages surrounding those staple markets. The Vecht and Regge provided a direct link to the Zuiderzee, where wood could easily be transported to Kampen, Enkhuizen, and Alkmaar. Another route would take the wood along the Ems river down to the Dollart bay, which provided the waterway connection to Groningen [18]. Baltic timber arrived in towns linked to the Hanseatic trade, as well as in towns bursting with shipbuilding activity [44–47], hence it was present e.g. in Bruges, Antwerp and Amsterdam, from where it was distributed to other cities.

Combining this historical and geographical information with the dense network of reference chronologies available for key supply areas (south Belgium, Germany, northeast France, and the Baltic region) allows a rough provenance analysis to be carried out aimed at discarding unlikely procurement areas. The outstanding lack of sound matches with chronologies representing the Meuse and Moselle river catchments, western Germany and the Baltic (Table 1), which where the areas supplying wood for panel paintings and sculptures in the southern Netherlands (including Brabant) during the 16th century [47–49], is a strong indicator that the wood used for the WWL did not originate from those regions. This result suggests by inference that the sculpture was made elsewhere than the workshops supplied by those areas.

#### 4.3. Production time and place

Given that sapwood (outermost part of the stem and branches in trees) was lacking in the sculpture it is not possible to estimate the felling date of the tree within a range of years. However, it is possible to estimate the minimum number of sapwood rings that are missing towards the bark in order to establish a *post quem* date for the felling of the tree. Considering the sapwood statistics proposed by [36] for Germany, we can estimate within a 95% confidence interval [10] that the tree was cut after 1495. [27] dates the sculpture circa 1500–1525; [9] proposes a date circa 1520; and [26] have recently proposed yet an earlier date circa 1500–1515.



**Figure 6.** Map indicating the probable provenance of the wood of the WWL sculpture in the east of the current Netherlands/Northwest of Germany (Münster region). Orange-filled dots indicate the towns where the timbers making up the NLEGW01 chronology were found. Those timbers also originated from the east of the Netherlands or the Münster region and were transported to those towns through the waterways indicated in the text. [1.5-column fitting image; colour]

Since sculptures were rather carved from moist, freshly cut wood [50,51], the number of years to account for drying and seasoning time can be disregarded. However, the number of heartwood rings still missing to the bark is unknown. Therefore, our results cannot narrow down the production date, making the interval between 1495 (earliest possible date based on dendrochronology) and 1525 (latest likely date based on art history) the most plausible one.

During that period, the production of carved wooden altarpieces reached its heyday in the Brabantine towns of Antwerp and Brussels (and Mechelen to a lesser degree)[8]. Having achieved an international reputation, those towns exported altarpieces both regionally as well as abroad [1]. However, Antwerp and Brussels were not the only centres of production. Other cities in neighbouring regions, such as Ghent and Bruges in the County of Flanders, Liège, Maastricht and Aachen in Limburg, and Utrecht in the North-



ern Netherlands were also home to talented wood carvers who produced altarpieces competing in quality with those from Brussels and Antwerp [8,52]. The migration of artists towards (and within) the Low Countries must have played an important role in the exchange and transfer of styles [52], which poses a challenge for the attribution of sculptures based solely on stylistic and technical features. Based on the provenance of the wood, a production workshop in Antwerp or other Brabantine town seems unlikely, given that during the late 15th and early 16th century, there was in Brabant a steady flow of imported timber from the Baltic area and from the Meuse river catchment, which seems to be in conflict with the provenance of the wood from the WWL sculpture in the east of the Netherlands or the Münster region in northwest Germany.

#### 4.4. A differentiated timber supply in Netherlandish workshops north and south of the Rhine river system

Publications about dendrochronological studies of Netherlandish sculptures are scarce, but the available studies provide valuable insights into the wood supply for this type of objects. [17] carried out a multidisciplinary study on three groups of sculptures from early 16th century altarpieces supposedly produced in Antwerp. Tree-ring analysis of 92 sculptures led to the dating of 69% of them with chronologies representing the Baltic region, with only one sculpture dating with local chronologies from the Meuse valley in southern Belgium. This result replicates the findings obtained by dendrochronological studies on panel paintings from Flemish and Dutch artists operating in major centres such as Bruges, Antwerp, Leiden, or Amsterdam during the first quarter of the 16th century, which demonstrated that the vast majority of the wood employed was Baltic oak [48,49,53,54]. When not of Baltic origin, the wood originated from the Meuse valley and western Germany [48]. Another dendrochronological study on a group of sculptures originating from the border-area of present-day Belgium, the Netherlands and Germany (Fig. 6), and attributed to the so-called Master of Elsloo, points at the Meuse river catchment as the main source of the timber [51]. The tree-ring series obtained from the WWL has been compared to all these sculptures, resulting in no significant matches (Fraiture, pers. comm.). Further dendrochronological research on 15th and 16th century historic buildings in the current Netherlands and Belgium suggests that cities south of the Nederrijn/Lek and Waal rivers, where the Brabantine production centres were located, were primarily supplied by wood imported from the Rhine and the Meuse river catchments (Van Daalen, unpublished), whereas construction in cities north of those rivers was supplied by the Rhine import, North-Rhine Westphalia, northern Germany, and Norway ([18,43]; Van Daalen, unpublished).

All those studies provide empirical evidence of the provenance of the timber that was available for construction and production of art objects in the Low Countries during the late 15th and early 16th century, and show a clear division in the distribution of timber imports north and south of the rivers.

Historical documents also provide interesting accounts about the supply of timber in workshops located in the northern Netherlands. According to [50] woodcarvers in Utrecht preferred local oak timber because transport costs were minimal and the wood was readily available in fresh to be cut into smaller pieces, which would prevent the formation of cracks and other deformations. [40] reported that woodcarvers in Utrecht also acquired wood from staple markets in Dordrecht, Deventer, Zutphen, Hasselt, Kampen and Zwolle, which were mostly supplied by the Münster region and the Rhineland [50]. This historical information demonstrates that wood from the area where the tree for the WWL sculpture was sourced was available in the Northern Netherlands not only for construction purposes (as demonstrated by the data in the

NLEDNW01 chronology), but also to be used in workshops. Therefore, although it is technically possible that wood from the east of the Netherlands and the Münster region would have reached Brabant via Dordrecht, it would be a rare exception, given the lack of wood from this provenance in panel paintings, sculptures and buildings.

## 5. Conclusions and outlook

Our interdisciplinary research has led to the hypothesis that a differentiated supply of wood, in terms of region of origin, was taking place in workshops of the Low Countries during the late 15th/early 16th century. If proven correct, it will imply that establishing the origin of the wood will be the first step towards a more precise determination of the provenance of Netherlandish works of art.

To attest this hypothesis, we propose new lines of inquiry. Dendrochronological data from historic buildings, archaeological timbers and art historical objects (panel paintings, sculptures, furniture, etc.) in the Netherlands and Belgium should be compiled to quantify and classify the distribution of timber imports according to area of provenance, location where the wood was used, and purpose. This should elucidate whether the possibility that timber from the Münster region would have found its way to Brabant is a plausible one. In addition to this, the empirical results should be cross-referenced with written sources. Lastly, the migration of artists towards and within the Low Countries should be integrated in provenance studies to fully understand the cultural depth and geographical ramifications of the transfer of styles, iconography and techniques. All this knowledge will furnish a solid empirical and (art)historical base for the attribution of Netherlandish art objects made of wood in the late-gothic and northern Renaissance periods.

The CT images were crucial to obtain a tree-ring series long and representative enough to date the sculpture. The valuable and often delicate nature of historical art objects subjected to dendrochronological research calls for the systematic implementation of non-invasive methods such as CT imaging. Those images can be stored in digital repositories to allow re-examination, exchange and reuse without having to access the real object again, thereby contributing to the preservation of such valuable historical works of art. Future efforts must therefore be directed at facilitating the implementation of imaging techniques in museums worldwide. Close collaboration between scientists of different disciplines (dendrochronologists, technical art historians, mathematicians, etc.), engineers, curators and conservators will be key to advance in that direction.

## Data availability

The datasets associated with this research have been made available on Zenodo. The CT scan of the sculpture *Woman with lantern* can be found through these DOIs: 10.5281/zenodo.3747192 and 10.5281/zenodo.3747327. The average tree-ring series obtained from the sculpture is linked to this one: <http://doi.org/10.5281/zenodo.4678193>

## Declaration of Competing Interest

none.

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