POLYTECHNIC OF NAMIBIA

Project title: The relationship between fallen coppicing tree species and floods in the Kuiseb River-flood plain in the Namib Naukluft Park, Namib Desert

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## Abstract

The force of the floods in the Kuiseb River and the debris they carries are known to damage trees. Trees with stems that are damaged and fell, respond to these changes by coppicing through the stem and roots. An attempt to assess the relationship between coppicing tree and floods was performed, by looking at different variables such as stem diameter of coppicing trees, number of coppices per stem, distance of tree from the active river channel, tree rings and volume of floods. The study was conducted in the Kuiseb River, near Gobabeb Research and Training Centre during July and August 2005. Only four tree species were encountered coppicing from the five wood tree species *(Acacia erioloba, Tamarix usneoides, Faidherbia albida* and *Euclea pseudebenus). Salvadora persica* was not observed coppicing. 3.2% of the estimated tree density was observed coppicing. The fallen coppicing trees did not appear to necessarily face the direction in which the river flows. The distance from the active river channel appears to influence the stem diameter of individuals for *F. albida. Tamarix usneoides* and *E. pseudebenus* had visible rings for all the samples taken whereas for *F. albida* only one sample had visible rings. The rings have not proven to be good indicators of flood frequency and volume.

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## 1. Introduction

The Namib Desert is one of the oldest deserts in the world (Seely, 1976; Ward, 1984). Namib is a Nama word that means "vast dry land". This desert stretches along the coast of southern Africa, measuring about 1,400 km in length and varying between 40 and 120 km in width (Yamagata & Mizuno, 2005). Apart from the two perennial rivers, the Kunene and Orange River, twelve major ephemeral rivers flow in western and north-western directions with catchments mostly in the upper streams of these river systems cross the Namib (Jacobson, *et al.,* 1995). The Kuiseb River is one of these twelve ephemeral rivers, which rises in the Khomas Hochland and flows toward the Atlantic Ocean through the central region of Namib Desert (Huntley, 1985). Seely (2004) describes these ephemeral river systems as linear oases, which supply valuable moisture to plants and animals.

Jacobson, *et al.,* (1995) noted that, The Kuiseb River flows only when sufficient rain has fallen in the catchment's area. The force of the flood and the debris it carries damages tree species, which are associated with this riverine system such as *Faidherbia albida* and *Tamarix usneoides.* As a result of the damages, roots and shoots of the trees respond to the changes in their environment by coppicing vigorously to form clumps of vegetation where previously only a single small upright tree stood. As a result of this vegetative growth, large clumps of tree form that are better able to withstand the force of the flood (Jacobson *et al.,* 1995). The term 'fallen coppicing trees' is used through this paper as trees with fallen stems that have shoots growing upward.

According to Grodek (pers. comm. 2005) a study was conducted in Israel in a similar ephemeral river system, in order to investigate the relationship of the damaged trees and floods. The study was conducted on *T. usneoides,* which also coppice vigorously after being damaged. It primarily focused on the relationship between tree rings and incident of floods. The finding of this study has indicated that there was a significant positive correlation between these floods and the number of rings. However, no similar study has been done in Namibia on the relationship between floods and fallen coppicing trees. By studying different components on the coppicing trees such as tree ring, number of coppices and on flood such as volume of flood per flood, better understanding of ephemeral rivers can be attained.

The Desert Research Foundation of Namibia (DRFN) is currently involved in a joint project called floodWater recharge of alluvial Aquifers in Dryland Environments (WADE) with partners from South Africa, Spain and Israel. The WADE project aims to assess long-term (decades to centuries) water resources in selected semi arid to hyper arid ephemeral river basins by determining long-term transmission losses from floods and quantifying floodwater recharge into alluvial aquifers (Anon, 2004). The project has nine work packages that are all aimed at contributing to the project aims. One of the work packages involves site characterisation which primarily entails vegetation studies (coppicing trees, canopy cover, evapotranspiration, stem diameter of tree species) Namibia and the South Africa region of Namaqualand were selected in Africa because those areas are the most arid zones of Southern Africa, facing major water scarcity problems.

This report presents the results of a systematic survey with regard to the relationship between floods and fallen coppicing trees. An attempt to determine whether there is any relationship between tree rings and floods was performed. The aim of this project was to assess the relationship between fallen coppicing tree species with stem rings and floods in the Kuiseb River-flood plain.

### 1.1 The objectives of the study were:

a) To determine which tree species are coppicing after falling.
b) To determine the density of coppicing trees in the study area
c) To determine the mean distance of each tree species from the active river channel
d) To determine the direction in which each individual coppicing tree have fallen.
e) To determine whether the coppicing tree species have true rings and whether there is any relationship between the number of rings and incidence of floods.

## 1.2 Personal objectives

(a) To learn more about the relationships between tree species and floods.

(b) To gain experience on how to conduct research projects.

(c) To be involved in research projects that will contribute to a better management of our natural resources.

## 1.3 Study area

The study was performed along the Kuiseb River in the Namib Naukluft Park, a national park established as a refuge for Hartmann's Zebra (*Equus zebra hartmannae*). At almost 50,000 km², this park is the largest conservation area in Namibia and one of the largest in the world,

The Kuiseb river has a catchments area of 15 500 $km^2$ (Jacobson *et al.,* 1995) and is classified under four different vegetation types (Geiss, 1971): 1. Central Namib, 2. Southern Namib, 3. Semi Desert and Escarpment zone and 4. Highland savanna (Appendix 1). The vegetation type of the study area has been classified as Central Namib (Geiss, 1971). This vegetation is typically woody, with dominant trees such as *Acacia erioloba, Tamarix usneoides, Euclea pseudebenus* and *Faidherbia albida* and sparse grass of *Cladoraphis spinosa.* The mean annual rainfall is only 27 mm, while the mean temperature per month is highest (24.8°C) in March and lowest (17.6°C) in August, and annual mean temperature is 21.1°C (Lancaster *et al.,* 1984).

# 2. Methods

## 2.1 Field Methods

Fieldwork was conducted from July 2005 to September 2005 near Gobabeb Training and Research Centre (15° 02' 28'' E, 23° 33' 41'' S). A 22.4 hectare (ha) area was surveyed, with an average canopy cover of 45% - 55 %. The study area was selected in such a way that it complements other studies that are being conducted by the WADE project in the same study area. Visual surveys commenced in the morning as early as 8h00 and terminated at 17h00 in the afternoon. To maintain consistency and reduce errors of observation, the same individual observers and methods were used. All fallen coppicing trees encountered were recorded. For every coppicing tree observed, tree species was identified, direction in which the tree has fallen and numbers of coppices were recorded. The following variables were also measured: distance of tree from the active river channel, stem circumference and the coppices circumference. The stem circumference was measured at 1.3 meters from the base of the stem. Samples of largest coppices were removed (cut) from the stem at 10mm from the base of the coppice for ring analysis. All trees observed coppicing were marked using a unique reference number on the flagging tape, in order to avoid over counting.

**2.2 Data analysis**

Tree density for the study area was estimated based on the data from vegetation study on 2.1ha. The total number of trees per tree species for the study area was estimated by multiplying the total number of trees per species with the total area in hectares (22.4ha). Due to a small sample size statistical analysis could not be performed for *A. erioloba.*

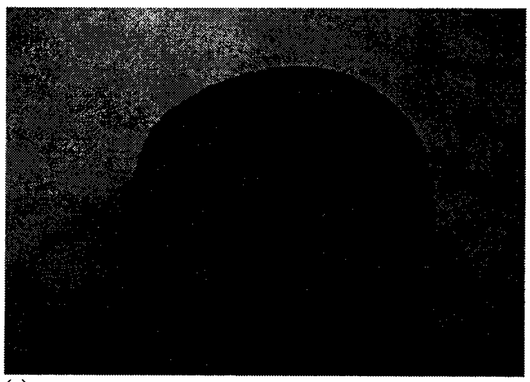
In order to determine the percentage of coppicing trees per species, the number of coppicing trees per species were divided by the density of trees per species and multiplied by 100. The percentage of all tree coppicing in the study area was obtained by dividing the total number of trees coppicing with the total estimated density and multiplied by 100.

Tree stem circumference measurements were converted to the stem diameter by multiplying the measurements with $\pi$. In order to determine whether the stem diameter affected or determined the number of coppices per stem, a linear regression was used.

The mean distance of trees (m) from the active was measured in order to give a sensible idea on the distribution of trees from the active river channel. A two-tailed Pearson product-moment correlation was also used to test any relationship between the distances of fallen coppicing tree to the active river channel and stem diameter of coppicing tree.

Eight different directions were used to determine the in which direction each individual tree has fallen. The direction in which the tree was facing was correlated to the direction in which the flow of the river shifted using an aerial photo of the study area in Arc view (version 3.1) (Appendix 2).

Samples for tree rings were polished using grit ranging from coarse (40 grain) up to very fine (1500 grains) to the highest standard of clarity. The rings were counted using a microscope (100 x magnifications) and a calliper was used to determine the distance between the rings in millimetres (mm) (Figure 1). The flood data were obtained from the Ministry of Agriculture, Water and Forestry and were used to calculate the volume of water per flood. Statistical analyses were performed based on the assumption that each ring represents a flood and that the distance between rings is determined by the volume of water of that particular flood. A two-tailed Pearson product-moment correlation was used to test for any existing relationship between the distance of the ring and volume of water of that certain flood.


(a)

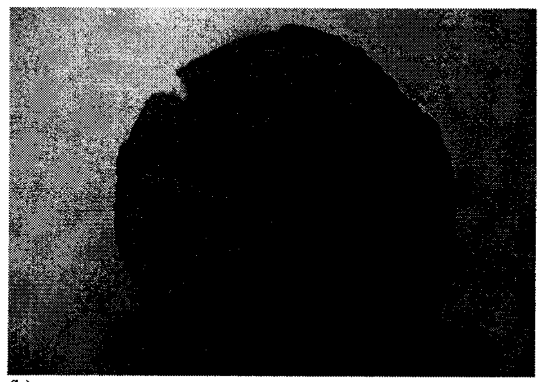

(b)

**Figure 1:** Photograph of a cross section for tree ring analysis for *F. albida* on the left (a) and the *E. pseudebenus* on the right (b)

## 3. Results

### 3.1 Tree density and coppicing tree density in the study area

The study area contain an estimated of 1483 trees, comprising of five (5) tree species (*Acacia erioloba, Faidherbia albida, Tamarix usneoides, Salvadora persica* and *Euclea pseudebenus)* (Table1). *Acacia erioloba* was the most abundant in the study area at 56.8% ($n$ = 843) of the total estimation in comparison to the other tree species. *Faidherbia albida* accounted for 21.6% ($n$ = 320). *Tamarix usneoides, E. pseudebenus* and *S. persica* were the least abundant at 9.4% ($n$ = 139), 8.6% ($n$ = 128)and 3.6% ($n$ = 53) respectively.

**Table 1:** The density (estimation) of tree per species and the number of tree coppices per species observed in the study area (22.4 hectares) with the percentage per each tree species.

| Tree species | Estimated number of trees per species | Total number of coppicing trees | Percentage (%) of trees per species | Percentage (%) of trees per species |
|---|---|---|---|---|
| *A. erioloba* | 843 | 2 | 56.8 | 0.2 |
| *F. albida* | 320 | 17 | 21.6 | 5.3 |
| *T. usneoides* | 139 | 22 | 9.4 | 15.9 |
| *E. pseudobenus* | 53 | 6 | 3.6 | 11.3 |
| *S. persica* | 128 | 0 | 8.6 | 0.0 |
| **Total** | **1483** | **47** | **100** | **3.2** |

However only 47 trees were observed fallen and coppicing in the study area, representing 4 tree species *(A. erioloba, F. albida, T. usneoides* and *E. pseudebenus).* Figure 2 shows that *Tamarix usneoides* was the most often encountered with 48% of the coppicing trees ($n$ = 22) whereas *F. albida* accounted for 36% ($n$ = 17) of the total observation. The *E. pseudebenus* and *A. erioloba* were the least observed trees coppicing at 13% ($n$ = 6) and *A. erioloba* at 4% ($n$ = 2) (Figure 2). *Salvadora persica* was not observed coppicing even though it was abundant in the study area.

Table 1 also shows the percentage of coppicing trees per species in relation to the total number of trees per species. In comparison to the estimated tree density in the study area, only 3.2% of the tree density was encountered coppicing. Although *A. eriloba* and *F. albida* were the most abundant tree species in the study area in terms of the estimated density per species, the analysis indicate that only 0.2% of *A. eriloba* and 5.3% of *F. albida* was coppicing in relation to its estimated tree species density. *Tamarix usneoides,* which was the most encountered tree species coppicing, had the highest percentage of coppicing individuals in relation to its estimated density (15.9%). *Euclea pseudebenus* which was the least observed coppicing in comparison to *T. usneoides* and *F. albida* also had a high percentage of coppicing trees in relation to its density (11.3%).

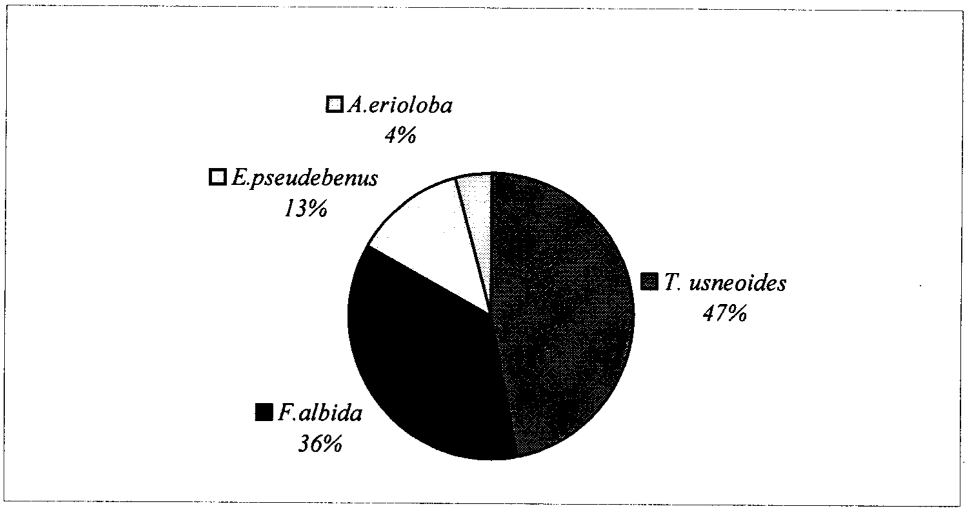



**Figure 2:** Percentage of coppicing individual per tree species in relation to the total number of tree coppicing

### 3.2 Direction of fallen coppicing trees

The direction in which each coppicing tree has fallen was determined and reveals that most coppicing trees observed do not necessarily face the direction in which the river is flowing (West). Most trees were observed facing North (38%) and North-West (34%) (Table 2). Only one individual tree was observed facing North-East (2.1%). In addition, no coppicing trees were observed facing South and South-East. *T. usneoides* was the most recorded trees species with individual trees facing six different directions. Other coppicing tree species were all observed facing less than three different directions.

**Table 2**: Number and percentage of individual trees tree species and direction in which tree has fallen. Dash means no observed tree species fallen facing that certain direction (-)

| Direction in which tree has fallen | Tree species | | | | Percentage (%) |
|---|---|---|---|---|---|
| | *A. erioloba* | *T. usneoides* | *F. albida* | *E. pseudebenus* | |
| N | 1 | 7 | 8 | 2 | 38.3 |
| NE | - | 1 | - | - | 2.1 |
| E | 1 | 2 | - | - | 6.4 |
| SW | - | 2 | - | 1 | 6.4 |
| W | - | 6 | - | - | 12.8 |
| NW | - | 4 | 9 | 3 | 34.0 |
| S | - | - | - | - | - |
| SE | - | - | - | - | - |

### 3.3 Distribution (mean distance) of coppicing trees from river channel and mean diameter of coppicing tree

Table 3 shows the mean distance of coppicing trees from the active river channel and mean stem diameter of coppicing tree species. The measurements of all distance of coppicing tree from the active river channel, stem diameter and diameters of the coppices were combined and converted into means. Table 3 indicate that *A. erioloba* was the furthest from the active river channel (86.4 m) and *F. albida* was the closest to the active river channel in terms of the mean distance.

*A. erioloba* had the biggest mean stem diameter (29.44 cm) in comparison to the other coppicing tree species. *T. usneoides* had the smallest mean stem diameter of 12.65 cm.

**Table 3:** Mean distance of coppicing tree from active river channel (m), stem and coppice diameter (cm)

| Tree species | Average Stem diameter (cm) | Average distance of coppicing tree from active river channel (m) |
|---|---|---|
| *A. erioloba* | 29.44 | 86.40 |
| *E. pseudebenus* | 13.71 | 26.03 |
| *F. albida* | 16.24 | 17.10 |
| *T. usneoides* | 12.65 | 39.59 |

### 3.4 Relationship between distances of coppicing trees, stem diameter and number of coppices per stem

Figure 3 is a scatter graph of the distances of coppicing trees from river channel and the stem diameter of coppicing trees. Pearson product-moment correlation indicates a significant negative correlation between the distance of coppicing tree from the active river channel and the stem diameter of tree for *F. albida* ($r$ = -0.657, $P$ = 0.004). However no significant correlation was observed from the analysis for the other coppicing tree species from the same variables. No statistical analyses were performed for *A. erioloba.*

Although linear regression analysis between the stem diameter and number of coppices per stem show positive correlations, the evidence was not strong enough to justify a conclusion that a significant relationship exists. These figure are *F. albida* ($r^2$ = 0.179, $n$ =17, $P$ = 0.09), *T. usneoides* ($r^2$ = 0.21, $n$ = 22, $P$ = 0.515) and *E. pseudebenus* ($r^2$ = 0.393, $n$ = 6, $P$ = 0.183).

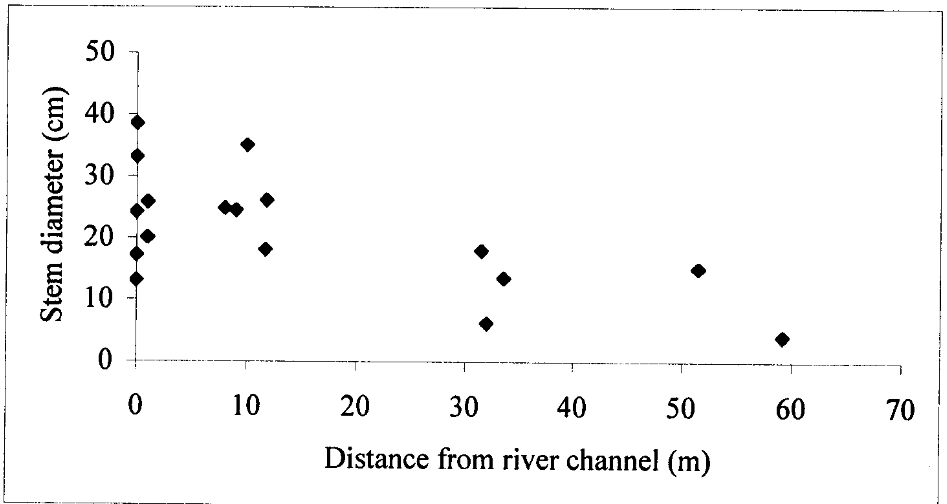



**Figure 3:** Scatter graph for the relationship between the distance of coppicing trees from river channel and stem diameter of coppicing trees

### 3.5 Relationship between rings, distance between rings and volume of water per flood

Pearson product-moment correlation was performed on the distance between rings (mm) and the volume of water ($m^3$) of the incidence of floods for each sample of each tree species. However, these simple correlation analyses display different statistical results for each sample of each species (Table 4). No significant correlation was obtained from the individual samples of each tree species. No ring analyses were performed for *A. erioloba* due to a small sample size observed. More samples were taken for *F. albida* but only one sample had visible rings.

**Table 4:** Correlation between the distance between rings (mm) and the volume of water ($m^3$) of each flood for each individual of each tree species. The *r* sign mean the measure of the correlation

| | | | Pearson correlation (two tailed) | |
|---|---|---|---|---|
| Tree species | Number of samples (disc)analysed | Sample no | *r* | *P* - value |
| *E. pseudebenus* | 3 | 1 | -0.661 | 0.339 |
| | | 2 | -0.620 | 0.295 |
| | | 3 | -0.148 | 0.905 |
| *T. usneoides* | 4 | 1 | -0.969 | 0.159 |
| | | 2 | 0.943 | 0.216 |
| | | 3 | -0.294 | 0.697 |
| | | 4 | 0.782 | 0.428 |
| *F. albida* | 1 | 1 | -0.782 | 0.428 |

* Indicates significant correlation ($P < 0.05$)

## 4. Discussion

### *4.1 Relationship between estimated tree density and coppicing tree density in the study area*

The study reveals that only 3.2% of trees in the study area were observed coppicing. *Salvadora persica* a sprawling, low growing shrub (Van Wyk & Van Wyk, 1997), was the only woody species in the study area which was not observed coppicing. This could possibly be because of its growth form, which could limit the damage caused primarily by floods on the species. *Acacia erioloba,* the most abundant tree species was the least often encountered coppicing. This could probably be due to the fact that they are mostly distributed far from the active river channel (Jacobson *et al.,* 1995), so they are not as exposed to flood intensity as other coppicing tree species. The other coppicing tree species (*F. albida, T. usneoides,* and *E. pseudebenus)* were the most frequently observed coppicing. This could be attributed to their mean distribution in distance form the active river channel. This conclusion is reinforced by fact that most observed coppicing tree species were the trees which were closer to the river channel. *Acacia erioloba,* which had the highest mean distance from the river channel, was the least frequently observed coppicing. Therefore, this could suggest that the tree growth form and the distribution of tree species from the river channel could be major factors determining occurrence of coppicing trees.

Comparisons between the direction of the river flow and the direction in which the trees have fallen has indicated that trees did not necessary fall in the direction in which the river is flowing as thought to be. This might be due to the fact that the trees are not essentially always damaged by the floods itself, but also by the logs the floods transport or the side on which the roots are exposed first.

*4.2 Relationship between distances of tree coppicing trees, stem diameter and number of coppices per stem*

There was a significant negative correlation between the distance of trees from the active river channel and stem diameter of *F. albida* (Figure 3). This could suggest that the further the tree is located from the active river channel the smaller the stem diameter. According to Jacobson *et al.,* (1995), during floods, the active river channel is recharged and is the -moistest area in dry season with the water table closer to ground surface groundwater making water more. The cause of the reduction in stem diameter as the tree is positioned further from the active river channel could be caused by the amount of moisture in the ground. However, positive correlations were also observed for *F. albida, T. usneoides* and *E. pseudebenus* from these variables. But the correlations were not significant to demonstrate any existing relationship.

Statistical analysis also indicates that the diameter of coppicing stem does not seem to determine the number of coppice on it.

*4.3 Tree ring analysis*

From the microscopic analysis, samples from *F. albida* had in some instances clear rings and in others poorly defined rings. According to February (1998), woody tree species in Southern Africa present more dendrochronology problems than most trees in other parts of world. Some species shows no ring boundaries, even in microscopic sections. In others, rings are not clearly defined, form several rings annually or are insensitive to climate change. This is consistent with this study, and this made ring analysis impossible for some samples from *F. albida* (Figure 1).

The statistical analysis between the distance between rings and volume of floods study revealed that there were strong positive correlations of some sample of different tree species, but these correlations were not significant.

The fact that no significant relationship between the distance of the rings and volume of each flood was obtain does not, necessarily imply that there is no association between these two variables. Samples from *T. usneoides* and *E. pseudebenus* had visible rings, but no significant correlations were obtained from this result. The fact that no significant correlation could be obtained this could suggest that there is no relationship or the sample size was to small and erratic results could be obtained.

There are some limitations to the study. In a paper to form a basis for climate reconstruction using dendrochronology February (1998) suggested that ring width measurements of 20 to 30 individuals trees of the same species should be taken and combined. The small number of samples taken for this study has proven insufficient to establish a statistically significant relationship between flood volume and distance between rings; therefore this could provide erratic results.

In summary, only 4 tree species were observed coppicing of the 5 woody trees were observed coppicing. The distance of coppicing *F. albida* does seem to influence the stem diameter. Coppicing trees did not appear to necessarily face the direction of the in which the river is flowing. *T. usneoides* and *E. pseudebenus* had visible rings for all the samples taken whereas for *F. albida* only one sample had visible rings. The rings have not proven to be good indicators of flood frequency and volume.

## 5. Recommendation

Ongoing monitoring should be encouraged and established on coppicing trees for long term studies. This will enable better understanding of the interaction between floods and coppicing trees. After floods, damaged trees should be marked with permanent metal tags and monitored in order to have the age estimation of coppices and correlate it to the coppice rings.

## 6. Acknowledgement

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