Optimizing the sampling scheme for hemispheric photography to assess the invasion of *Acacia longifolia*

Jan Lehmann[1], André Große-Stoltenberg[1]

Introduction

Acacia longifolia, a tree from Southwest Australia that has been introduced for dune stabilization, is now causing ecological problems in Portugal by reducing the species number and diversity by up to 50% in invaded compared to non-invaded areas (WERNER ET AL. 2010, RASCHER ET AL. 2011). One reason for the reduction of biodiversity is caused by the increase in leaf area index (LAI) and the consequent decreasing transmitted gap light due to the presence of *Acacia longifolia* (RASCHER ET AL. 2011). Hemispheric photography may therefore be used to examine the effective LAI in order to identify areas of *Acacia* invasion due to the changes in LAI compared to the native pine species.

Aim of the Study

The aim was to reduce the expenditure of time for the extensive hemispherical photography measurements by optimizing the sampling design without losing information about the impact of *Acacia longifolia* on the LAI and consequently on the invasion situtation.

Materials & Methods

A fixed design of 116 (D116) hemispheric pictures was used to examine the effective LAI. Hemispherical photography is an indirect method using a fisheye lens (Sigma F2.8 EX DG) to gather information about solar radiation in forests (JONCKHEERE ET AL. 2005). The lens was placed in vertical position under the canopy at height of 1.5 m (h_1), facing magnetic north resulting in 180° pictures with the zenith in the centre of the image and the horizons at the edges. The pictures were used to determine the effective LAI integrated over the zenith angle 0 to 75° calculated with Gap Light Analyzer (WELLES & NORMAN 1991).

The plot that was investigated had a dimension of 50 by 100 m. For interpolation between the pictures the “Inverse Distance Weighting” (IDW) method was applied. The radius *r* of the circle projecting the LAI information can be calculated using the tangent of the maximum zenith view angle (75°), being 3.78, the height at which the camera is taking the pictures (h_1) and the mean of the *Acacia* height in the given plot (h_2)

$$r = 3.78 \times (h_1 - h_2)$$

With the given formula it is possible to calculate the minimal amount of pictures needed to obtain information about the *Acacia* invasion (MAJASALMI ET AL. 2011). The sample designs were, therefore, chosen to cover for information about all trees starting at 3 m, 3.8 m (average *Acacia* height), 4 m and 5 m height comprising of 78, 54, 28 and 14 pictures, respectively.

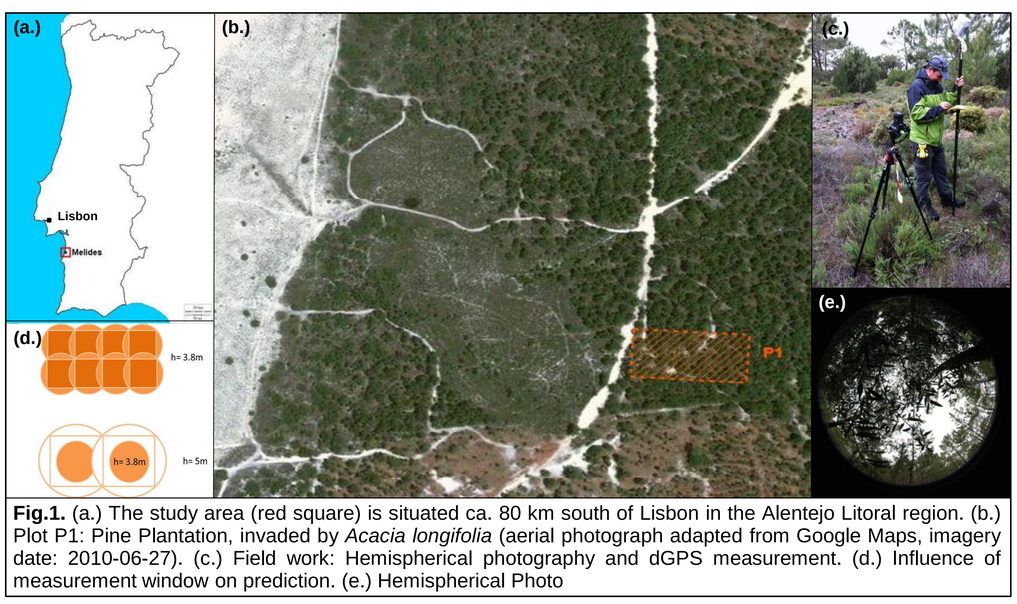

Fig.1. (a.) The study area (red square) is situated ca. 80 km south of Lisbon in the Alentejo Litoral region. (b.) Plot P1: Pine Plantation, invaded by *Acacia longifolia* (aerial photograph adapted from Google Maps, imagery date: 2010-06-27). (c.) Field work: Hemispherical photography and dGPS measurement. (d.) Influence of measurement window on prediction. (e.) Hemispherical Photo

Results & Discussion

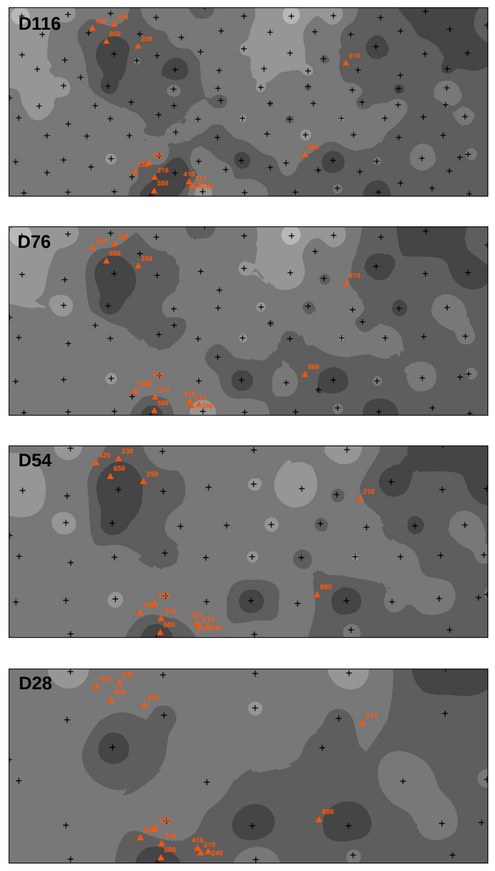

Fig.2. IDW interpolation of LAI values: Presented are the different measurement designs. The original design is labeled as D116 and the optimized designs are labeled with their number of images, respectively.

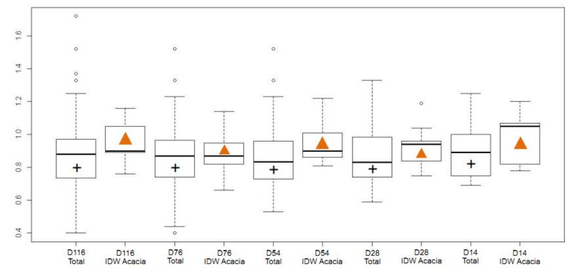

Fig.3. Boxplot: Median values of the Leaf Area Index for the entire study plot. Values were calculated based on hemispherical photos (Total) or interpolated values from Inverse Distance Weighting (IDW *Acacia*). Different numbers of hemispherical photos were used (D14-D116).

The results (Fig.2.) indicate the suitability of the sample design of 54 pictures to detect areas of *Acacia* invasion. In none of the presented designs it is possible to identify single *Acacia* trees. Only groups can be detected. Even with a lesser amount of pictures information about areas of *Acacia longifolia* invasion can be obtained. Only in close proximity to the measurement points, information about the lower part of the vegetation is guaranteed. Using only 28 pictures (4 m height), there are already areas, which are not clearly identifiable as being invaded. With 14 pictures (5 m height) an even greater amount of information about the lower height is lost, as presented in the Fig.1d. The invasion situation seems less severe as in reality.

This is confirmed by the box plots (Fig.3.) of the different setups, still showing comparable median and standard deviation for 116, 76 and even for 54 pictures, while for 28 and 14 pictures the LAI median for the interpolated *Acacia* values increases. The fewer pictures used in a sample design the greater knowledge is needed about the position of the target species prior designing of the study.

Conclusion

The average height of the target species, here *Acacia longifolia,* is a reasonable approach to calculate the amount of pictures needed. Case-dependent, the amount of pictures may be further reduced if the structure of the plot to be analyzed is known. For areas in which only taller plants are present the distance between pictures can be increased.

References

JONCKHEERE I., FLECK S., NACKAERTS K., MUYS B., COPPIN P., WEISS M. & BARET F. (2004): Review of methods for in situ Leaf Area Index determination - Part I. Theories, sensors and hemispherical photography. Agricultural and forest meteorology 121

MAJASALMI T., RAUTIAINEN M., STENBERG P., & RITA,H. (2011): Optimizing the sampling scheme for LAI-2000 measurements in a boreal forest. Agricultural and Forest Meteorology 154–155 (2012) 38–43

PEPERKORN R. (2005): Schlüsselfaktoren der Invasivität von Acacia longifolia -Experimentelle Untersuchungen im Vergleich zu Heimischen Arten Mediterraner Sandökosysteme. Dissertation. Fakultät für Biologie. Universität Bielefeld, Bielefeld.

RASCHER K. G., GROßE- STOLTENBERG A., MÁGUAS C., MEIRA-NETO J. A. A. & WERNER C. (2011): Acacia longifolia invasion impacts vegetation structure and regeneration dynamics in open dunes and pine forests. In: Biological Invasions

WERNER C., ZUMKIER U., BEYSCHLAG, W. & MÁGUAS C. (2010): High competitiveness of a resource demanding invasive acacia under low resource supply. In: Plant Ecology 206: 83–96.

[1] Institut für Landschaftsökologie, Westfälische Wilhelms Universität Münster
e-Mail: j_lehm11@uni-muenster.de

Arbeitsgruppe Angewandte Landschafts-ökologie/Ökologische Planung
www.uni-muenster.de/OekologischePlanung