Fire history in southern Sweden during the past 11500 years: relationships with climate and human impact, and the role of fire in forest dynamics

Cui Qiao-Yu[1], Marie-José Gaillard[1], Geoffrey Lemdahl[1] and Jonas Wäglindl[2]

1 School of Pure and Applied Natural Sciences, Linnaeus University, 39182 Kalmar, Sweden; qiaoyu.cui@lnu.se, marie-jose.gaillard-lemdahl@lnu.se, Geoffrey.lemdahl@lnu.se
2 County Administrative Board of Kronoberg, 35186 Växjö, Sweden; jonas.waglinbd@lansstyrelse.se

Summary: *Three bog sites in the province of Småland, S. Sweden, were studied for macrocharcoal and microcharcoal with the aim to reconstruct the Holocene fire history of the study region. In parallel, the local forest/vegetation histories at the three sites were inferred in quantitative terms (in percentage cover of plant taxa within the relevant source area of pollen RSAP) using the Sugita's Landscape Reconstruction Algorithm (LRA). Additional information on the fire history was obtained from findings of fire-dependant coleopteran, charred plant remains and identified large charcoal fragments. A synthesis of the results, complemented by a study of fire scars (1600-1900 AD) at one of the sites, provides detailed information on the regional and local fire history in terms of long-term trends in fire activity and, for some periods, fire frequency, intensity, and size. We also examined the importance of the vegetation composition as one of the causes behind differences between local fire histories at different locations. Moreover, archaeological records and earlier studies of past climatic conditions in the study region were used to discuss the role of human activities vs. climate characteristics. The results and conclusions from these studies were compared to similar investigations in Europe.*

Key words: *Holocene, fire history, Landscape Reconstruction Algorithm, human impact, climate, southern Sweden.*

INTRODUCTION

It is well recognised that studies of past fire regimes and their causes (human and/or climatic) are useful to understand the long-term ecological effects of fire on vegetation communities (Whelan, 1995). Further, information on the long-term fire history and its effect on forest dynamics and insect fauna may provide useful insights for forest management aiming at maintaining biodiversity in these ecosystems of the boreo-nemoral zone of NW Europe.

There are only two studies of long-term fire history for the entire Holocene in southern Sweden, i.e. the charcoal records at Stavsåkra and Storasjö in the province of Småland (Greisman and Gaillard, 2009; Olsson and Lemdahl, 2009, 2010; Olsson *et al.*, 2010). Additional information on the fire history was obtained from findings of fire-dependant coleopteran, charred plant remains and identified large charcoal fragments. The synthesis of results, complemented by a study of fire scars (1600-1900 AD) at one of the sites, provided detailed information on the regional and local fire history in terms of long-term trends in fire activity and, for some periods, fire frequency, intensity, and size (Olsson *et al.*, 2010). These studies suggested different fire histories at the two sites separated by only *ca.* 50 km. Therefore, a third site close to the western study site, Notteryd, was selected with the aim to check whether the fire history at Stavsåkra was representative of the region N. of Växjö and to further study the variability of long-term fire regimes in time and space. These studies also had the goal of improving our understanding of long-term fire ecology. In order to assess the relationships between fire and vegetation/plant composition, we used the Landscape Reconstruction Algorithm (LRA) of Sugita (2007) to infer percentage cover of the plants involved. The study of Notteryd is not finalized yet. It will be presented at the conference and published elsewhere.

RESULTS AND DISCUSSION

In this paper, we briefly present the long-term fire history at the two sites Stavsåkra and Storasjö, the comparison of the two fire records, and the information provided by the application of the LRA. The methods are described in Figure 1 that compares the records of macro- and micro-charcoal with the LRA-based reconstruction of local plant abundance (main taxa) and the record of dated clearance cairns (Skoglund, 2005). The two Holocene micro- and macro-charcoal records indicate that fire was more frequent during the Early and the Late Holocene periods. Moreover, frequent fire activity during the Late Holocene was mainly related to human land-use as shown by forest clearances from *ca.* 1500 cal BC (Late Bronze Age) (Fig. 1) (Greisman and Gaillard, 2009; Olsson *et al.*, 2010; Olsson and Lemdahl, 2009, 2010).

During the Mid Holocene, fire activity was higher at Storasjö than at Stavsåkra, which was most probably related to the higher abundance of pine at Storasjö during that period (Fig. 1). The coleoptera data indicate that species dependant of fire were present during the periods of high and frequent fire activities. Findings of a coleoptera species dependant of grazed *Calluna* heaths confirm that *Calluna* heaths developed from 1500 cal BC (Fig. 1) and were maintained until recently (*ca.* 1850 AD). There is a good correspondence between the

periods of fire activity inferred from the macrocharcoal record at Storasjö from *ca.* 1400 AD and the reconstruction of fire regimes from the study of fire scars (Wäglind, 2004; Marlon *et al.,* 2010). According to the study of fire scars and the identification of the macro-charcoal found in the peat (mainly grasses and other herbs), the fire regime was obviously human-induced to improve fodder for grazing animals in the pine forest. This is shown by the fact that 1) fires were relatively small in area, but very frequent (a mean interval between fires of *ca.* 20 yrs) and 2) no macro-charcoal from trees was found (Olsson *et al.*, 2010).

CONCLUSIONS

Fire (both climate- and human-induced) obviously played an important role in the Holocene forest dynamics of the boreo-nemoral zone of southern Sweden and in the long-term maintenance of floristic and coleopteran diversity. The general trends in the fire history of southern Sweden are strikingly similar to the pattern inferred from the Global Charcoal Database (Power *et al.*, 2008). The application of the LRA (Sugita, 2007) provided additional information that neither pollen percentages nor pollen accumulation rates could offer. It showed that pine was significantly more abundant at Storasjö than at Stavsåkra during the entire Holocene, which explains the different local forest histories.

ACKNOWLEDGEMENTS

We acknowledge the financial support from the Faculty of Natural Sciences and Technology of the Linnaeus University, Kalmar, Sweden.

REFERENCES

GREISMAN, A., GAILLARD, M.J., 2009. The role of climate variability and fire in early and mid Holocene forest dynamics of southern Sweden. *Journal of Quaternary Science* 24 (6), 593–611.

MARLON, J., CUI, Q., GAILLARD, M.-J., MCWETHY, D., WALSH, M., 2010. Humans and fire: Consequences of anthropogenic burning during the past 2 ka. *PAGES News* 18 (2), 80-82.

OLSSON, F., LEMDAHL, G., 2009. A continuous Holocene beetle record from the site Stavsåkra, southern Sweden: implications for the last 10600 years of forest and land use history. *Journal of Quaternary Science* 24 (6), 612–626.

OLSSON, F., LEMDAHL, G., 2010. A forest history for the last 10 900 years at the site Storasjö, southern Sweden: implications from beetle assemblages. *Journal of Quaternary Science* 25 (8), 1211–1221.

OLSSON, F., GAILLARD, M.J., LEMDAHL, G. *et al.*, 2010. A continuous record of fire covering the last 10,500 calendar years from southern Sweden – The role of climate and human activities. *Palaeogeography, Palaeoclimatology, Palaeoecology* 291 (1-2), 128–141.

POWER, M.J., MARLON, J., ORTIZ, N. *et al*., 2008. Changes in fire regimes since the Last Glacial Maximum: an assessment based on a global synthesis and analysis of charcoal data. *Climate Dynamics* 30 (7-8), 887–907.

SKOGLUND, P., 2005. *Vardagens landskap: lokala perspektiv på bronsåldernus matriella kultur.* Almqvist & Wiksell International: Stockholm, 228.

SUGITA, S., 2007. Theory of quantitative reconstruction of vegetation II: all you need is LOVE. *The Holocene* 17 (2), 243–257.

WÄGLIND, J., 2004. *En översiktlig brandhistorisk analys av Storasjöområdets naturreservat, Kronobergs län*. Master Thesis. Linnaeus University, Kalmar.

WHELAN, R.J., 1995. Fire ecology – an introduction, *The Ecology of Fire*. Cambridge University Press.

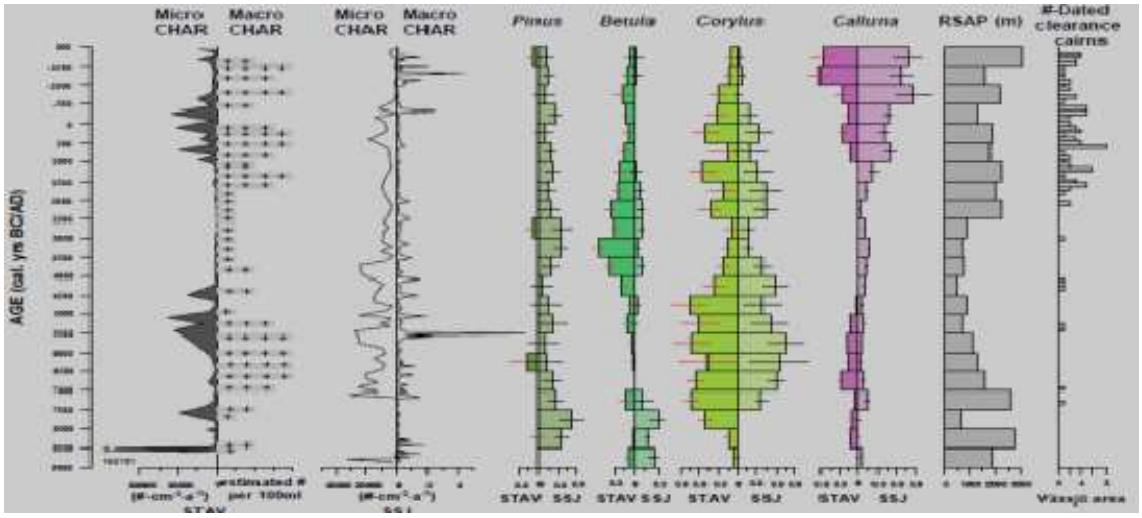

FIGURE 1. Records of macroscopic and microscopic charcoal from Stavsåkra (STAV) and Storasjö (SSJ), and LRA-based estimates of local abundance of main taxa (with Standard Errors) within the relevant source area of pollen (RSAP; Sugita, 2007), i.e. varying between 500 and 3500 m radius during the course of the Holocene; the grey bar chart on the right side shows the number of dated clearing cairns per 100-a interval in the Växjö region (Skoglund, 2005), indicating extensive forest clearing in the region of the Stavsåkra study site. The number of macrocharcoal fragments (≥0.25 mm) per 100ml were estimated at Stavsåkra as follows: +=0-10, ++=10-100; +++=100-1000; ++++=≥1000. At Storasjö, a continuous macrocharcoal analysis following the method developed in Australia (see references and description in Olsson et al.*, 2010) was performed and provides the number of macrocharcoal per cm² and year.*