Geogr. Fis. Dinam. Quat.
37 (2014), 23-27, 3 figg.

DOI 10.4461/GFDQ.2014.37.3

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FIRST RESULTS OF THE PARTICIPATORY APPROACH FOR MONITORING SUPRAGLACIAL VEGETATION IN ITALY

Abstract: Pelfini M. & Leonelli G., *First results of the participatory approach for monitoring supraglacial vegetation in Italy.*

The relationship between glacier fluctuations and vegetation dynamics makes the vegetation system a precious archive of data not only for studying climatic trends but also for assessing glacier history and recent movements. The increasing supraglacial debris coverage, that is currently affecting many glaciers, offers new habitats for animals and plants, including trees. On this basis, since 2011 the Italian Glaciological Committee has started a participatory project for annually monitoring the Italian supraglacial vegetation in order to record the progressive debris covered glacier surfaces colonization, in relation with glacier location, altitude, aspect. In the first three years of monitoring, the 27 observed glaciers have allowed to add new information for those glaciers where supraglacial vegetation was already known or studied (Miage, Brenva and Belvedere Glaciers) and to detect new glaciers presenting vegetation colonization.

Key Words: Supraglacial vegetation, Debris covered glaciers, Italian Glaciological Committee, European Alps.

Riassunto: Pelfini M. & Leonelli G., *Primi risultati dell'approccio partecipativo per il monitoraggio della vegetazione epiglaciale in Italia.*

Fluttuazioni glaciali e dinamica della vegetazione presentano legami molto stretti tanto che i sistemi vegetazionali costituiscono un prezioso archivio di dati sia per l'analisi delle variazioni e delle tendenze climatiche, sia per la ricostruzione della storia glaciale e lo studio della dinamica attuale. Il progressivo incremento della copertura detritica epiglaciale che si sta verificando sui ghiacciai alpini, consente la colonizzazione da parte di specie animali e vegetali, inclusa la vegetazione arborea, ove le condizioni lo consentono. Nell'ambito delle attività di monitoraggio del Comitato Glaciologico Italiano, dal 2011 è stata inclusa quella relativa al monitoraggio partecipativo della vegetazione epiglaciale, al fine di identificarne le fasi iniziali e la progressiva colonizzazione. Nei primi tre anni di monitoraggio, i 27 ghiacciai analizzati hanno permesso sia di aggiungere nuove informazioni per i ghiacciai per i quali la vegetazione epiglaciale era già nota o studiata (Miage, Brenva, Belvedere), sia di identificare nuovi ghiacciai interessati da colonizzazione da parte della vegetazione.

Termini Chiave: Vegetazione epiglaciale, Ghiacciai neri, Comitato Glaciologico Italiano, Alpi europee.

INTRODUCTION

Glacier fluctuations and vegetation dynamics are among the most evident responses to climate change in high mountains temperature-limited environments. For example, climate drives with a certain delay (response time) both glacier advancing or retreating phases (Benn & Evans, 2010) and vegetation changes like tree-line shifting (e.g. Nicolussi & *alii*, 2005; Leonelli & *alii*, 2009a; 2011a; Pennisi, 2013). Within other climate-driven dynamics, the colonization of expanding proglacial areas (ecesis) during warming periods, when glacier shrinkage occurs (McCarthy & Luckman, 1993), is a topic of particular interest for studying the interactions between physical and biological components of the environment. Instead, during cooling periods of the Holocene and the Little Ice Age, glacier advances have destroyed trees and the forests growing in the proglacial areas. The retrieval of logs and wood remnants buried in till or into moraine systems has allowed important reconstruction of the Holocene glacier fluctuations (e.g. Holzhauser & Zumbuhl, 1999; Holzhauser, 2002; Coulthard & *alii*, 2013).

Overall, the vegetation system represents a precious archive of environmental data not only for studying the climate impacts but also for assessing the glacier history and recent dynamics (e.g. Reyes & *alii*, 2006; Johnson & Smith, 2012; Leonelli & Pelfini, 2013). Moreover, tree rings may record with annual and seasonal resolution, climatic and environmental information (e.g. Pelfini & *alii*, 2006; Speer, 2010) and changes in the climatic signal itself (Leonelli &

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Field data was collected by the authors and by the following persons that are here acknowledged: R.S. Azzoni, V. Bertoglio, M. Bettio, I. Bollati, A. Franchino, A. Fusinaz, V. Garavaglia, G. Gilli, M. Gilli, C. Iulita, G. Losapio, G. Mortara, E. Motta, M. Motta, M. Pecci, S. Scapinello, R. Serandrei Barbero, A. Théodule, E. Tosatto, M. Vagliasindi, G. Vergnano, D. Zannetti. This resarch was developed in the framework of the PRIN 2010-11 (2010AYKTAB_006) "Dinamica dei sistemi morfoclimatici in risposta ai cambiamenti globali e rischi geomorfologici indotti", local coordinator Prof. C. Smiraglia, national coordinator Prof. C. Baroni. The authors thank the President of the CGI Prof. C. Baroni for actively promoting this research.

alii, 2009b; Coppola & *alii*, 2012). Through dendroclimatic analysis (e.g. Nicolussi & *alii*, 2009), old trees may also allow the reconstruction of long temperature records for the periods prior to the instrumental data (for the Alps: Büntgen & *alii*, 2005; Coppola & *alii*, 2013) and somewhere also the reconstruction of past glacier mass balance (Nicolussi, 1994; Lewis & Smith, 2004; Leonelli & *alii*, 2011b; Wood & *alii*, 2011; Malcomb & Wiles, 2013).

A relatively recent and peculiar signal of climatically-driven changes occurring in the glacial environment is given by the supraglacial vegetation colonization of debris-covered glacier tongues (e.g. Pelfini & *alii*, 2007). The analysis of tree rings from supraglacial vegetation can be used for the spatio-temporal characterization of climate change impacts on glaciers and for the reconstruction of the recent debris covered glacier surface dynamics. The supraglacial debris coverage, deriving from permafrost degradation and from macrogelivation processes affecting the glacial valley slopes and from the increasing glacier ablation rates, represent a new habitat for animals and plants (Pelfini & *alii*, 2007; Caccianiga & *alii*, 2010, Gobbi & *alii*, 2011). This situation is typical for debris-covered glaciers which number is increasing as a response to climate warming (Carturan & *alii*, 2013). When the supraglacial debris layer is thick enough, when the glacier tongue reaches altitudes below the treeline and when the glacier surface velocity is low, the glacier tongue surface can be colonized also by trees (fig. 1A; Pelfini, 2009).

Supraglacial trees may record during their life both the climatic and the environmental signal including the glacier surface movements, thus becoming a source of glaciological information that can be derived through the analysis of the tree growth anomalies (Leonelli & Pelfini, 2013). Growth disturbances are induced by the complex of the glacial movements (glacier flow, differential ablation, glaciokarst phenomena) able to destabilize trees and tilt them. After their germination, trees move downvalley, following the glacier surface velocity, performing a sort of annual registration of the substrate movements, archived in the tree-ring characteristics (compression wood, stem eccentricity, growth anomalies, resin ducts by mechanical stress).

Trees and vegetation growing on debris-covered glaciers have been reported for Chile, Nepal, Alaska and also Switzerland and Italy (e.g. Pelfini & *alii*, 2012). Moreover some notes about the presence of herbaceous vegetation growing in the vicinities or on the glacier surface have been reported for example in the annual glaciological survey carried on by the Italian Glaciological Committee (CGI). The CGI is monitoring the glaciers frontal variation since the end of the 19th century and more recently also the glacier annual mass balances (Comitato Glaciologico Italiano, 1914-2012). The annual glaciological surveys provide a wealth of information also on the debris coverage. During the 2011 summer meeting the CGI approved the monitoring of the supraglacial vegetation in order to record the progressive colonization of the supraglacial debris coverage by vegetation and its development in term of diffusion and altitudinal shifts. The goal of this participatory project is to yearly acquire data and information about

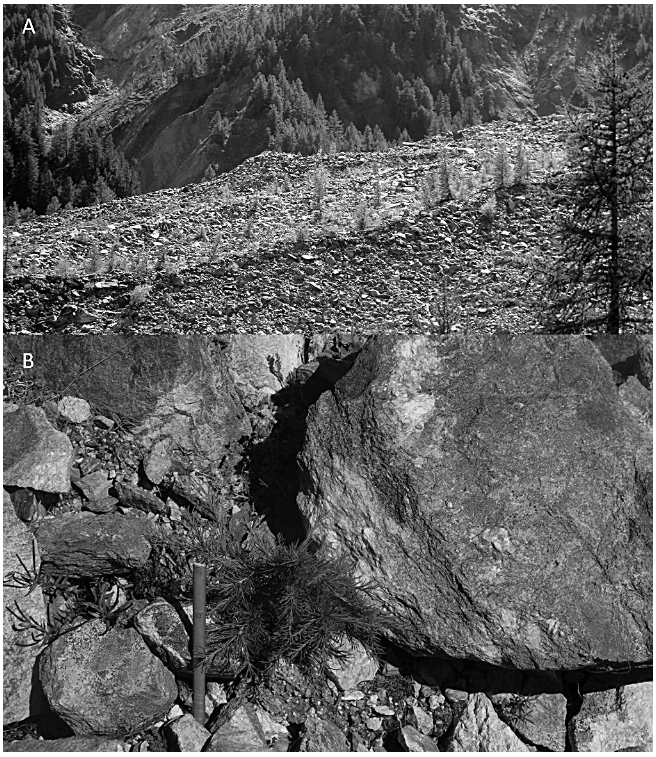

FIG. 1A - Inner portion of the Miage Glacier south lobe; supraglacial trees growing along the margin are dragged outside the glacier by the debris sliding along the lateral escarpment (Photo G. Leonelli, September 2012). 2B - One of the supraglacial larch specimens growing at the highest altitudes on the Miage Glacier tongue at about 2050 m a.sl. The presence of relatively stable fine debris between rock debris and blocks creates a microhabitat that let the tree growth, also together with some herbaceous specimens of at least 5 other species and 1 spruce sapling, on the left (Photo A. Franchino, August 2013).

the presence of supraglacial vegetation and debris. Field data are collected independently by volunteers and anyone interested in the project and the collection of the reports and related materials is managed by the Università degli Studi di Milano that has been developing dendroglaciological analyses and researches in this sector since long time.

The aim of this short note, after a brief presentation of the criteria for the collection of field data, is to present the first results of three years of monitoring of the supraglacial vegetation in Italy.

METHODS

A form has been predisposed in order to easily collect information about the presence of supraglacial vegetation; the monitoring campaign on supraglacial vegetation is indeed open to people interested of glaciology and hikers who are already frequenting the glacial environment for their own purposes and want to collect data on supraglacial vegetation. The campaign is supported by the CGI and more information can be found on its website at the address: http://www.glaciologia.it/rilevamento-vegetazione-epiglaciale/?lang=en. This web page provides the predisposed form that can be filled and sent via e-mail together with descriptive photos. The form allows to standardize the different data: name and address of the surveyor; name and code of the glacier; altitude of the glacier front; date of the survey; number of attached photos; description of the site with the indication of the debris coverage: absent, scarce, widespread, abundant; description of the vegetation cover: none, scarce, diffused, abundant, differentiating between vegetation types: grass, shrubs and trees. The classes were fixed only in qualitative terms both for debris and vegetation covers because the form has to be used also by common people and too complex or specific information could be not well accepted. In the form, a simplified sketch map of the debris cover tongue and the position of the supraglacial vegetation is also required.

The received material, including the photos, is used only for scientific research purposes and the monitoring results are made available on the official website of the Italian Glaciological Committee (www.glaciologia.it).

RESULTS

In the three years of monitoring, overall 24 surveyors have monitored 27 glaciers. The surveyed glaciers are: Vedretta d'Amola, Lana, Rosso Destro and Valle del Vento (for Trentino-Alto Adige); Toula, Tressonnet Meridionale, Verra Grande, Lys, Mont Gelé, Chérillon, Soches-Tsanteleina, Mont Braoulé, Rutor, Pré de Bard, Miage, Brenva (detached tongue of dead ice), Orientale di Morion, Rosa dei Banchi and Jumeaux (for Valle d'Aosta); Aurona, Belvedere, Locce Nord, Carro Occidentale and Capra, Ciamousseretto (for Piemonte), Forni (for Lombardia) and Calderone (for Abruzzo) (fig. 2B). The latter is the only glacier not belonging to the European Alps but to the Apennines.

Although the number of glaciers reported is limited, some assessments are already possible, especially with regard to the presence of supraglacial debris and the total number of glaciers that are colonized by vegetation. Out of the 27 surveyed glaciers (fig. 2A and fig. 3), 13 presented an abundant debris coverage of the tongue, namely: Lana, Belvedere, Locce Nord, Miage, Brenva, Vedretta d'Amola, Verra Grande, Aurona, Lys, Valle del Vento, Chérillon, Forni and Calderone. For what concerns the herbaceous vegetation, the Miage Glacier is the only one presenting an abundant coverage, whereas the Brenva (detached lower tongue of dead ice) and the Locce Nord glaciers present a minor vegetation density (diffused cover). Referring to the other vegetation categories, the Miage Glacier presents an abundant colonization of both shrubs and trees, also well developed (3-4 m height) while the Brenva Glacier presents a «diffused» shrub and tree cover. First stages of herbaceous vegetation cover are reported for the Calderone, Forni, Ciamousseretto, Capra, Vedretta d'Amola, Rosa dei Banchi, Lys and Belvedere glaciers (for the latter also sparse shrubs and trees are reported). Together with the information in the forms, 97 detailed and panoramic photos that facilitated the interpretation of the

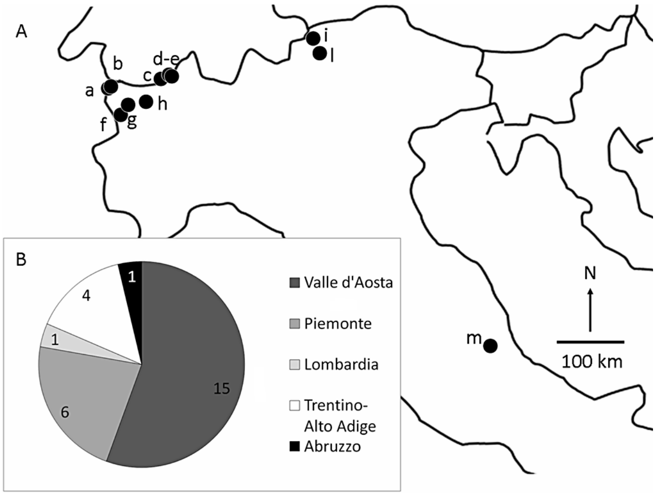

FIG. 2A - Position of the glaciers presenting supraglacial herbaceous vegetation as reported by the surveyors over the first three years of monitoring: a.Miage, b.Brenva, c.Lys, d-e.Belvedere-Locce, f.Capra, g.Ciamousseretto, h.Rosa dei Banchi, i.Forni, l.Amola, m.Calderone. Same information available at http://www.glaciologia.it/wp-content/uploads/vari/SupraglacialVegetation_2013.zip. 2B - Number of glaciers surveyed with the predisposed form for monitoring supraglacial vegetation and debris, subdivided by region.

data contained in the forms were collected via e-mail. Additionally, a great number of photos has been received and stored for the Miage Glacier after the last survey of 2013 (by A. Franchino). For this glacier the characteristics of the growing supraglacial forest has been confirmed. The most common tree specimens on this glacier are larches (*Larix decidua* Mill.) and spruce (*Picea abies* Karst.) that, according to the new data collected, allow to assess that supraglacial trees of about 15 cm height have colonized the glacier tongue up to an altitude of about 2050 m a.s.l. (fig. 1B).

DISCUSSION

The progressive increasing number of debris-covered glaciers is recognized as a climate-related trend that in-

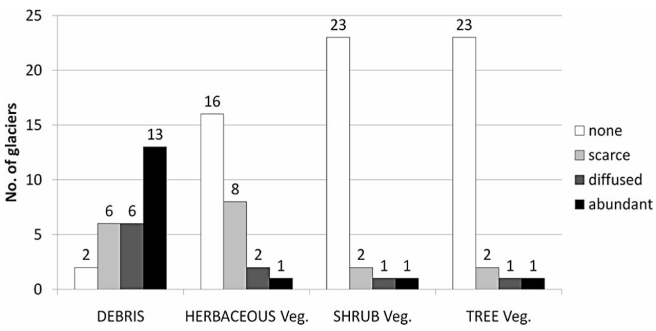

FIG. 3 - Number of glaciers surveyed, subdivided by class of debris cover and of supraglacial vegetation cover, roughly corresponding to (as explained in the Discussion chapter).

volves glacierized mountain chains at the global scale. Debris-covered glaciers are common features in the Himalaya, Karakoram and Tien Shan ranges, Andes, Alaska and New Zealand and they are becoming a typical feature also in the European Alps (Pelfini & *alii*, 2012). Analogously to proglacial areas where tree colonization advances following the patterns of glacier retreat and of the climatic inputs, debris-covered glacier surfaces can be colonized by vegetation as well and this phenomenon has become a key indicator of environmental changes and of climate-change impacts on the cryosphere. Where supraglacial trees have been studied from the geomorhpological point of view, several researches have been carried out: this is the case of Miage Glacier. Here the climatic and glaciological signals recorded in the tree-ring growth anomalies has allowed the reconstruction of the tongue's past surface movements for the last 20 years (Pelfini & *alii*, 2007; Leonelli & Pelfini, 2013) and the detection of the mean survival age of the supraglacial trees. Recent researches on the distribution of supraglacial trees (Pelfini & *alii*, 2012) have shown that the trees are more densely distributed, especially along the internal margin of the northern lobe. The southern lobe instead, is home to the oldest larch specimens, with trees showing an average age ranging 50-60 years.

The tree colonization above the glacier is strongly controlled by the substrate characteristics and by its instability (the combination of ice and debris). The dendrochronological analysis of the growth anomalies for the period 1987-2006 combined with the distribution and characteristics of the supraglacial trees has allowed the identification of areas of higher stress (Leonelli & Pelfini, 2013). At this glacier, the most advanced researches include the study of stable isotopes in the tree rings that has allowed to understand the type of water (glacier meltwater or meteoric) absorbed by the trees as demonstrated by the first results obtained from the Miage Glacier ice-contact lake Lago Verde (Leonelli & *alii*, 2013).

Currently, most of the glaciers in the European Alps are not colonized by vegetation, however the majority of them are also not (yet) covered by debris or they are covered by debris only in the lower portion of their tongues. Among the debris-covered glaciers, different situations can be find (altitude, aspect, steepness, surface glacier velocity). As mentioned before, the conditions for tree colonization (i.e. altitude, glacier surface stability, presence of fine debris) are rather restrictive for life establishment.

In this context the proposed monitoring of supraglacial vegetation has become a key instrument for assessing the impact of climate change on the analysed climate-sensitive landscapes. Moreover, the participatory approach has allowed to involve motivated people on topics about climate-change impacts on the mountain environment and to rapidly collect data from most of the regions presenting glaciers in Italy. We underline that on-field observation is recommended for detecting the first stages of supraglacial vegetation colonization because sparse herbaceous vegetation and isolated young trees and saplings (less then few centimetres high) can hardly be detected with the resolution commonly available for aerial and satellite images.

For what concerns the qualitative evaluation of debris and of vegetation covers, by considering that the maximum debris cover is 100% and the maximum vegetation cover currently observed on the most colonized glacier (the Miage Glacier) is about 10%, the various qualitative classes based on perception may be subdivided into respective quantitative classes of percentage covers: none 0%, scarce 1-20%, diffused 21-80%, and abundant 81-100%, for debris cover; none 0%, scarce 1-2%, diffuse 2.1-8%, abundant 8.1-10% for vegetation cover. This more detailed information could be included in the first revision of the online form and some examples of well-filed forms will be uploaded on the website for helping the surveyors towards a more efficient use of the form.

CONCLUSIONS

The rapid changes occurring in the glacial environment require a monitoring not only of glaciological and climatic parameters (e.g. glacier mass balance, glacier ablation rate, summer temperature, precipitation) but also of the biological component which is increasing its interactions with the physical environment. Supraglacial vegetation represent an important indicator of the early-stage changes that are deeply involving the Alpine glacial environment. Moreover, when supraglacial vegetation include trees, it can be seen also as an important source of information on glacier surface stability/instability over time. The annual survey of the Italian glaciers proposed since 2011 by the CGI allow to collect important information on the ongoing changes in the glacial environment. Moreover, the monitoring represent the only way to detect the first phases of the new colonization. For the next campaigns, we stress the importance of collecting new data from the whole southern side of the Alps and at the international level.

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(Ms received 1 October 2013; accepted 30 March 2014)