Earth and Planetary Science Letters 489 (2018) 111–122

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Addressing the contribution of climate and vegetation cover on hillslope denudation, Chilean Coastal Cordillera (26°–38°S)

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ARTICLE INFO

Article history:
Received 30 October 2017
Received in revised form 19 February 2018
Accepted 20 February 2018
Available online xxxx
Editor: A. Yin

Keywords:
denudation
hillslope
climate
biota
cosmogenic nuclide
Chile

ABSTRACT

The Earth surface is modulated by interactions among tectonics, climate, and biota. The influence of each of these factors on hillslope denudation rates is difficult to disentangle. The Chilean Coastal Cordillera offers a strong climate and vegetation gradient from arid and unvegetated in the North to humid and vegetated in the South. A similar (convergent) plate tectonic boundary lies to the West of the Coastal Cordillera. We present eight depth profiles analyzed for *in situ*-produced cosmogenic ^{10}Be in four study areas. These profiles reveal denudation rates of soil-mantled hillslopes and the depth of mobile layers. Depth profiles were investigated from both S- and N-facing mid-slope positions. Results indicate the depth of the mobile layers in the four study areas increase from N to S in latitude. When mixing is present in the mobile layers they are completely mixed. In the S- and N-facing hillslopes of each study area, mid-slope positions do not show a systematic change in depth of the mobile layers nor in denudation rates based on cosmogenic depth profiles. From N to S in latitude, modelled denudation rates of hillslopes increase from ∼0.46 to ∼5.65 cm/kyr and then decrease to ∼3.22 cm/kyr in the southernmost, highest vegetation cover, study area. Calculated turnover times of soils decrease from ∼30 to ∼11 kyr and then increase to ∼22 kyr. In this work, the increasing denudation rates are attributed to increasing mean annual precipitation from N to S. However, despite the ongoing increase in precipitation from N to S, the denudation rate in the southernmost location does not continue to increase due to the protective nature of increasing vegetation cover. This indicates a vegetation induced non-linear relationship with denudation rates.

1. Introduction

The Earth surface, where atmosphere, lithosphere, water, and life interact, is governed by tectonic and climatic processes. However, climate conditions affect biota (fauna and flora), which in turn influences physical erosion (e.g., soil mixing by bioturbation, rain splash, tree throw, soil creep) and chemical weathering processes (e.g., mineral dissolution by microbial activity and/or acidity). These complex and often non-linear interactions as well as their effect on Earth surface processes are difficult to study and quantify (e.g., Corenblit et al., 2011). One avenue to study and quantify Earth surface processes is the application of cosmogenic nuclides.

Measurements of cosmogenic nuclide concentrations enable quantitative determination of rates of Earth surface processes over a wide variety of spatial scales, from catchment-wide denudation rates from measurements of river sediments (e.g., Brown et al., 1995; Granger et al., 1996) to soil production rates from measurements of saprolite (e.g., Heimsath et al., 1997). Soil production rates (i.e. the rate of conversion of saprolite to soil) can be calculated from the cosmogenic nuclide concentration of saprolite located at the interface between the mobile and immobile layers of a depth profile (Fig. 1). This calculation assumes steady-state conditions of constant soil production, soil depth, soil bulk density, and identifies the degree of mixing within the soil layer (e.g., Heimsath et al., 1997; Granger et al., 1996; Schaller et al., 2009). While visual verification of possible mixing of the mobile layer is not easy, measurements of several samples in a cosmogenic depth profile can evaluate the depth of mixing. In the case of no mixing, the cosmogenic nuclide concentration decreases exponentially with depth (Fig. 1). In the case of well-mixing, the cosmogenic nuclide concentration in the mixed soil layer is homogeneous. Furthermore, the knowledge of the denudation rate based on depth profiles and the depth of the mobile layer allow the calculation of

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https://doi.org/10.1016/j.epsl.2018.02.026
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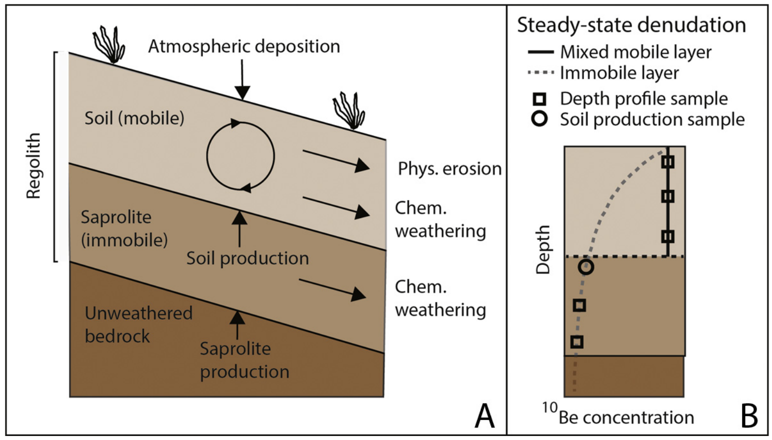

Fig. 1. Schematic view of a steady-state eroding soil-mantled hillslope. A) The unweathered bedrock is overlain by the regolith which consists of the immobile saprolite and the mobile soil, B) The *in situ*-produced ^{10}Be concentration is homogeneous in a well-mixed mobile soil whereas the concentration decreases exponential with depth in the immobile saprolite. Several samples (squares) need to be collected for depth profile analysis, whereas only one sample (point) is required for the determination of the soil production rate.

the soil turnover time (Fig. 1). The soil turnover time is the time a mineral grain resides in average in the mobile layer before it is getting eroded.

Owen et al. (2011) investigate the climatic and biotic influences on soil production rates in soil-mantled hillslopes in the Chilean Coastal Cordillera (Fig. 2) by comparing measurements from tectonically similar settings. As previous work, this study focuses on the Coastal Cordillera because of similar lithologies exposed along its approximate 3000 km length, and the similar (convergent) plate boundary to the West where subduction of the Nazca (and formerly Farallon) plate have been ongoing over hundred-million-year timescales. Thus, the western South America plate boundary provides one of the most spatially and temporally consistent plate tectonic settings possible over a large range of latitudes. Furthermore, a dramatic latitudinal gradient in precipitation rates is present along the Coastal Cordillera and produces diverse vegetation zones. Owen et al. (2011) determined soil production rates on active soil-mantled hillslopes located around our northernmost study area. Their sampling is located in three climatically different regions including: 1) hyper arid (∼24°S); 2) arid (∼26°S); and 3) semi-arid (∼30°S). Whereas mean annual precipitation increases from <2 mm/yr to 119 mm/yr, the vegetation

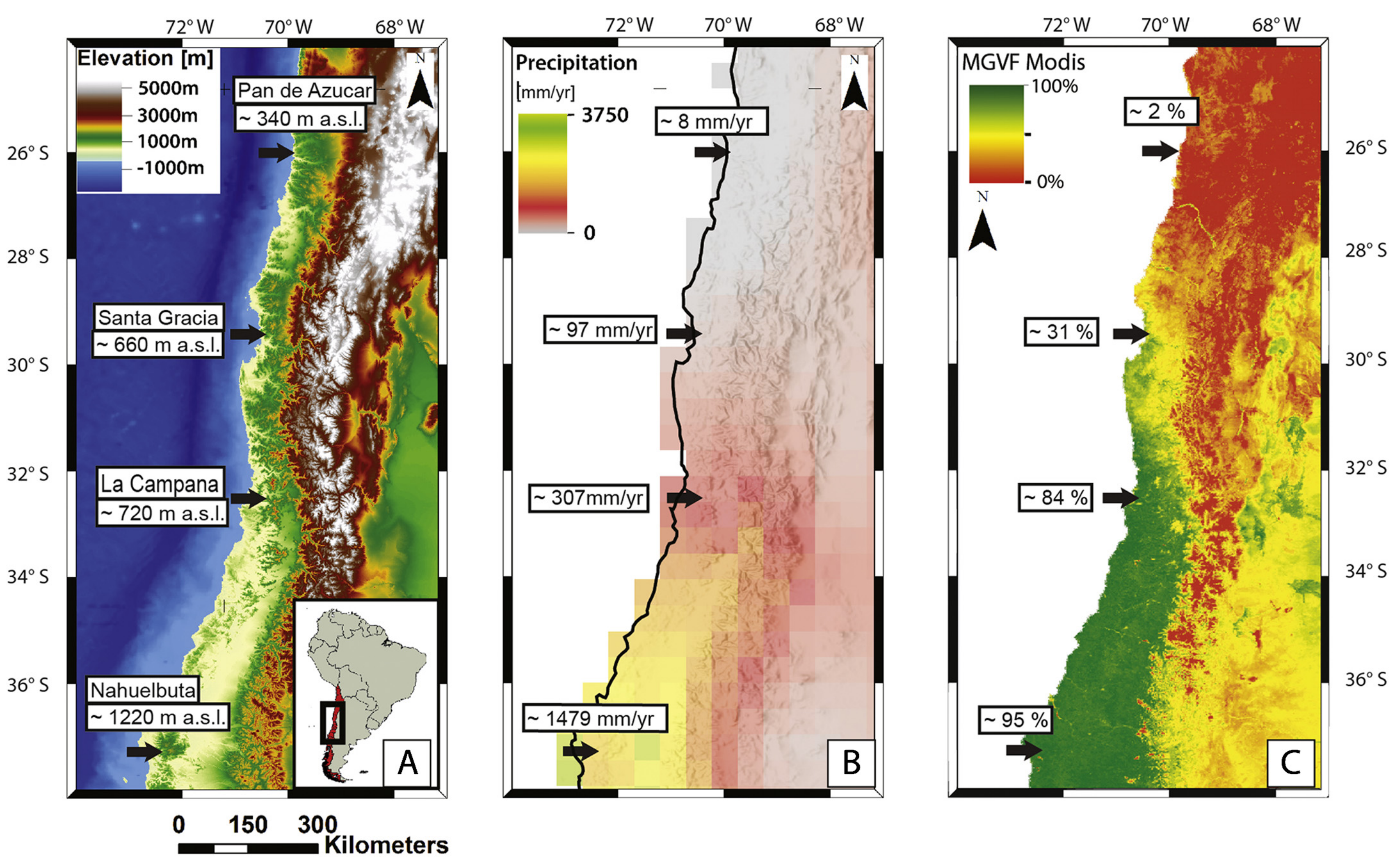

Fig. 2. Overview of the four study areas located in the Chilean Coastal Cordillera shown from 24° to 38°S: A) Digital elevation model showing from N to S the location of Pan de Azúcar, Santa Gracia, La Campana, and Nahuelbuta; B) Mean annual precipitation (Karger et al., 2017); C) Relative vegetation cover (Broxton et al., 2014). From N to S the mean annual precipitation rate and the relative vegetation cover increase from 8 to 1479 mm/yr and ∼2 to ∼95%, respectively.