Seasonal forecast of High Altitude Wetland phenology in the tropical Andes based on MODIS snow cover and TRMM precipitation data

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Introduction

High Altitude Wetlands of the Andes (HAWA) belong to a unique type of wetland within the semi-arid high Andean region. HAWA are surrounded by arid grasslands of the central Andes situated in the most arid part of their range from 4000 m a.s.l. on the western slopes of the Andes up to more than 5000 m a.s.l. (Fig. 1). These wetlands are extremely fragile water features sensitive to climate changes and human disturbances such as livestock grazing playing a critical role for breading of Andean camelid species like Alpaca (Vicugna pacos). Climate conditions of the high Andean region are very rough and although situated in the tropics snow events can regularly occur in these altitudes. Usually small snow fall events generate snow cover below the permanent snow line which melts within a short time due to high solar insolation in the tropics. The aim of the study is to analyse the impact of snow fall pattern and rain fall to forecast seasonal phenology of HAWA sites. The study contributes valuable information for improvement of rangeland management and for investigation on regional wetland hydrology.

Fig. 1: Study region (black frame) and HAWA sites reported in literature (green)

Data and Methods

Annual changes in precipitation and HAWA land cover in 2000/2001 (reference year) and derivation of perennial HAWA (HAWA$_P$) and temporal (HAWA$_T$) as HAWA subtypes
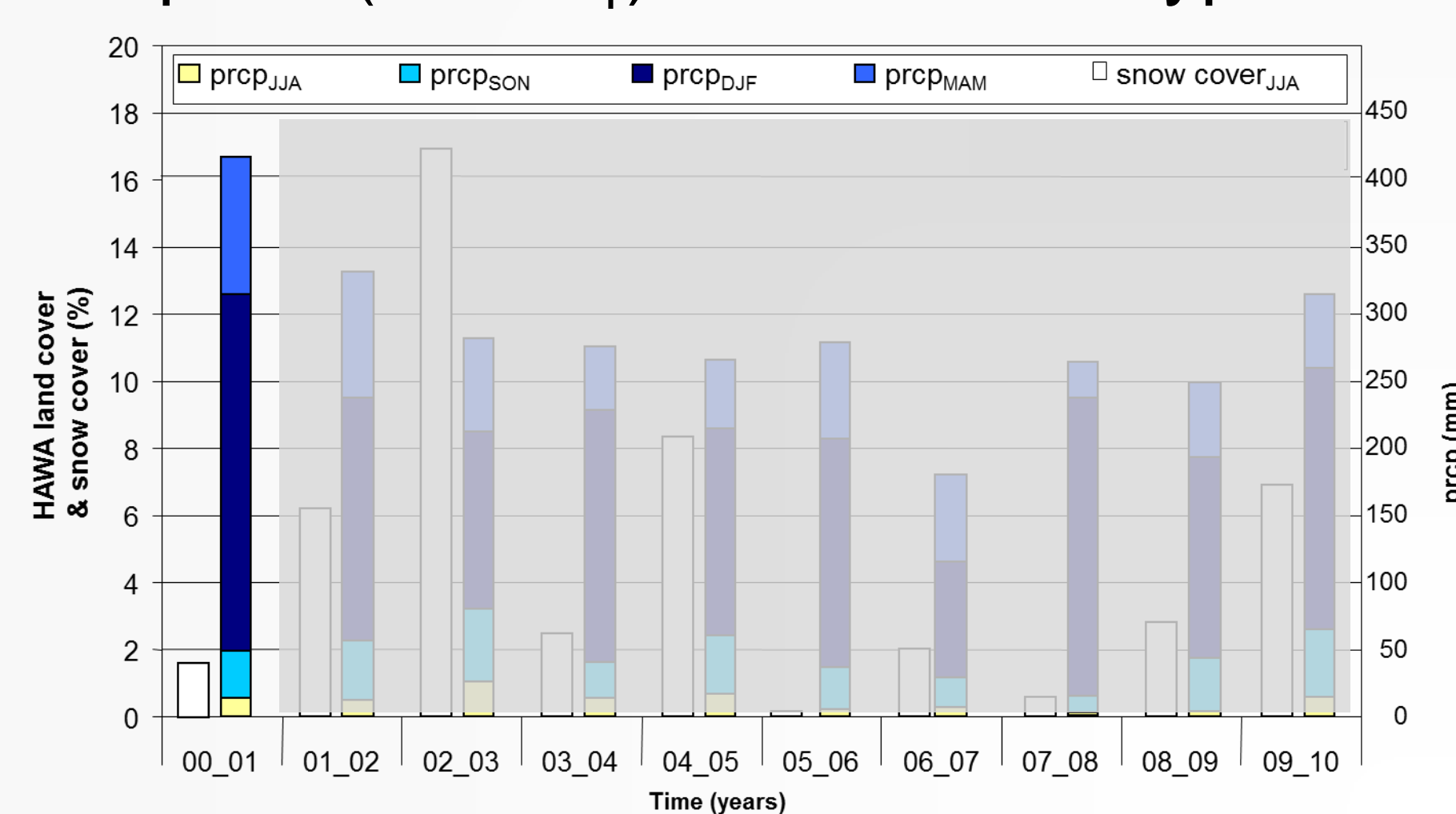

Fig. 2: Annual/3-month precipitation (Tropical Rain Measurement Mission - TRMM 3B43) and snow cover 8-day (Moderate Resolution Imaging Spectroradiometer - MOD10A2).
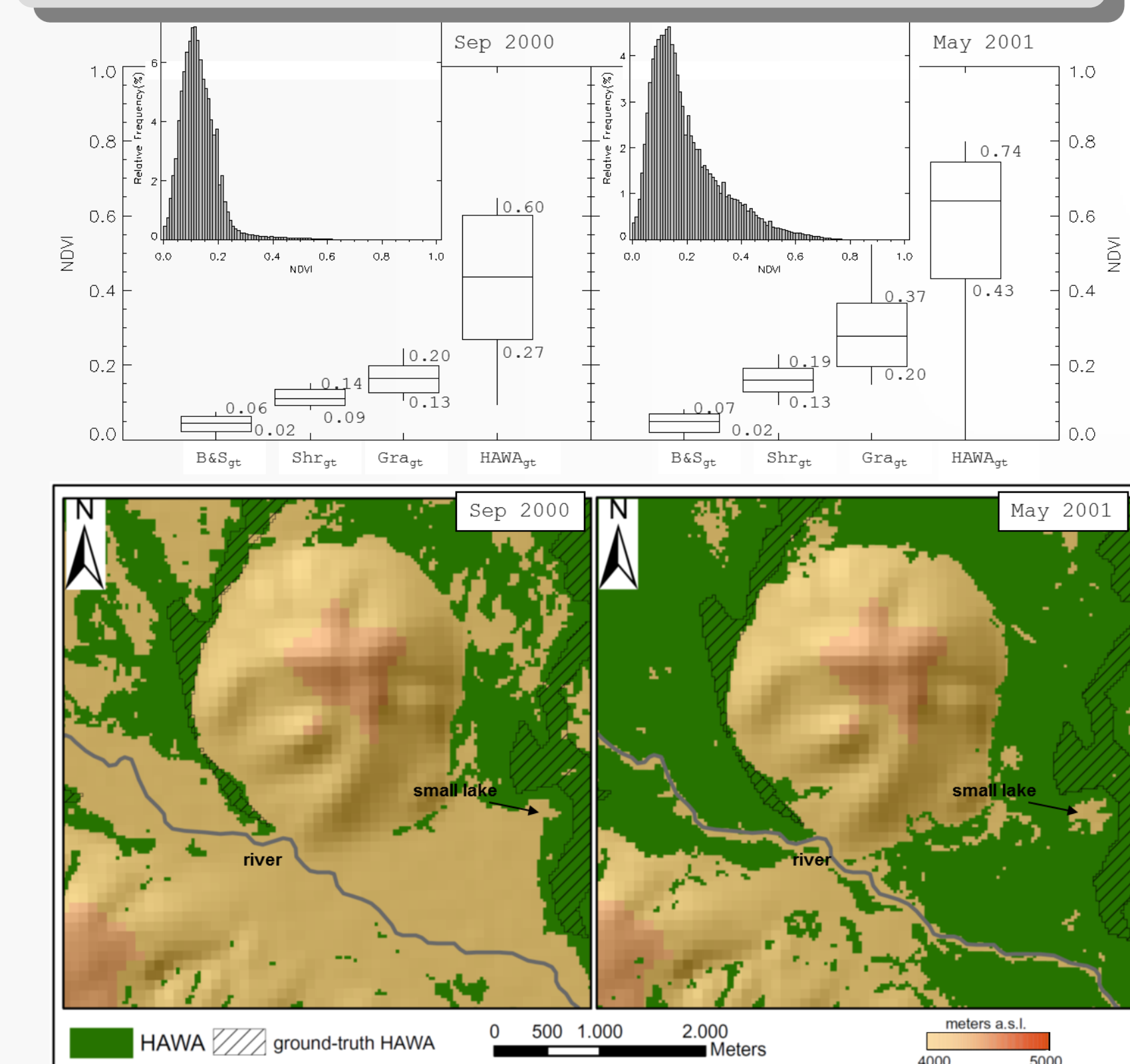

Fig. 4: Box plots (upper part) thresholds for each ground-truth land cover dataset of September 2000 and May 2001. Spatial patterns of mapped HAWA (subset) applying thresholds as depicted in the respective box plots.

Multi-annual changes in precipitation and HAWA subtypes land cover from 2000 till 2010
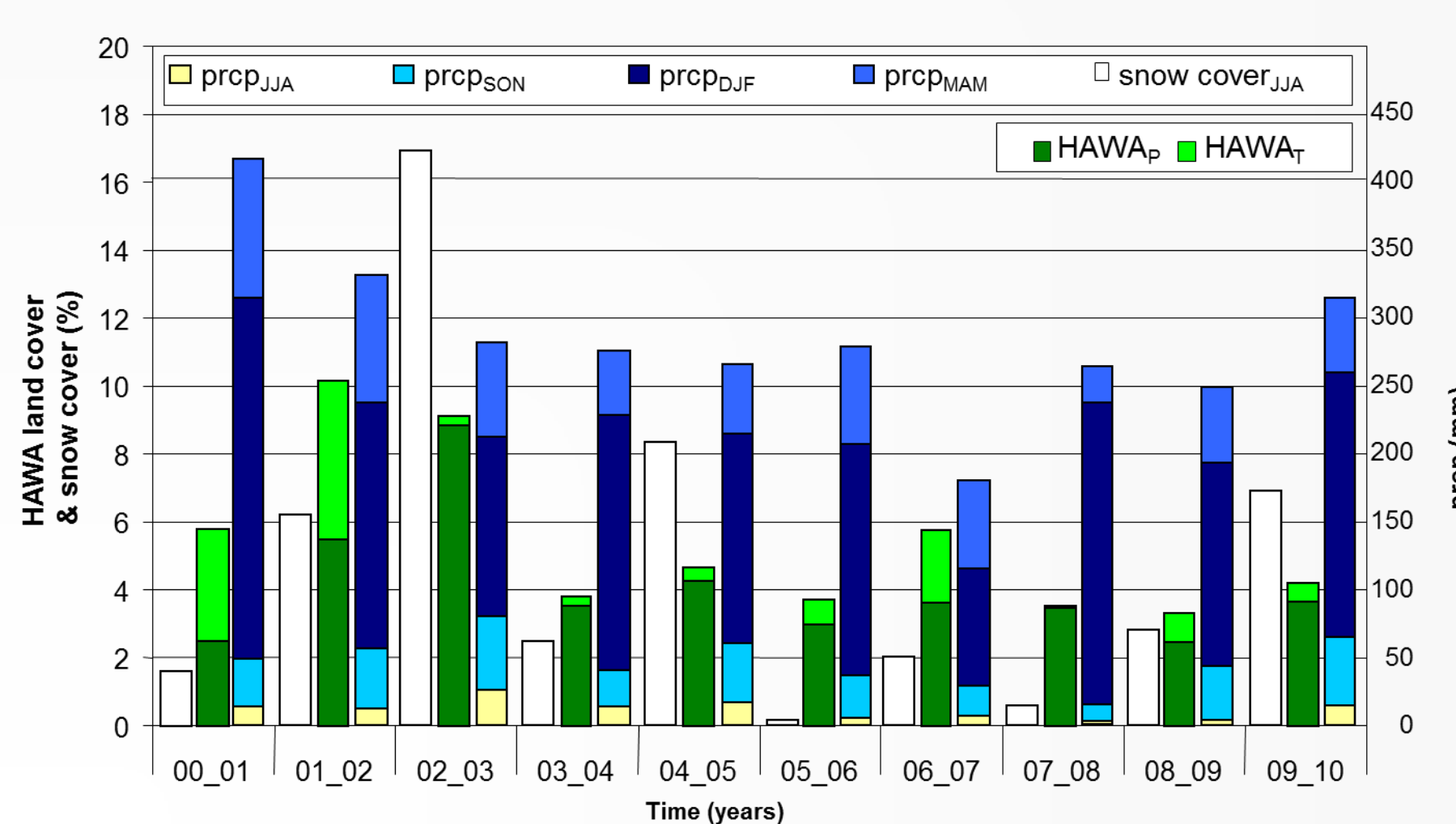

Fig. 3: Annual time series of HAWA$_P$ and HAWA$_T$ land cover, 3-month precipitation (TRMM (3B43) from 1 June 2000 to 31 May 2001(00_01) till 1 June 2009 to 31 May 2010 (09_10) and 3-month snow cover (JJA).
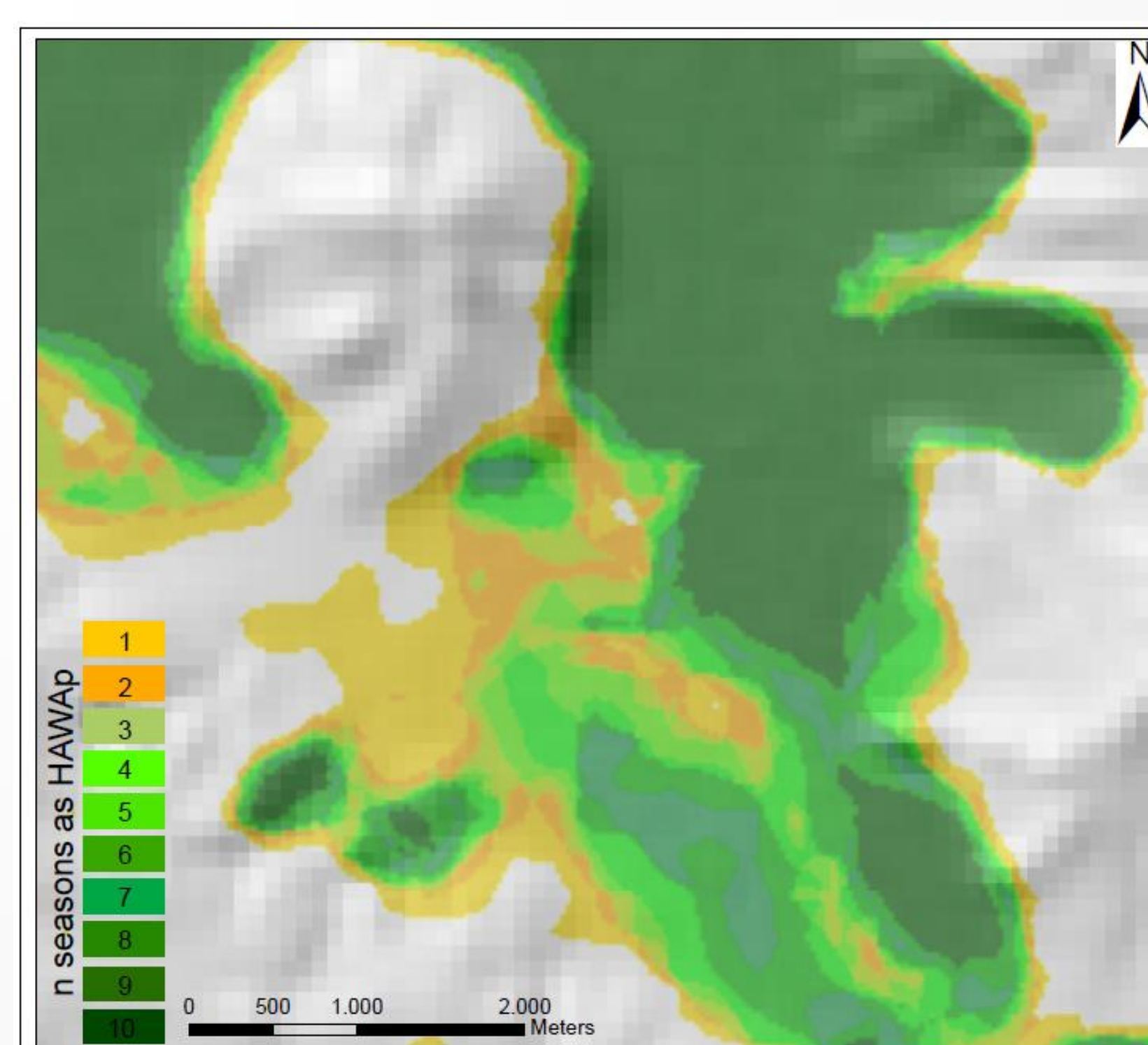

Fig. 5: Annual changes in spatial extend of HAWA$_P$. Numbers in coloured rectangular boxes indicate number of years where areas were mapped as HAWA$_P$.

Results

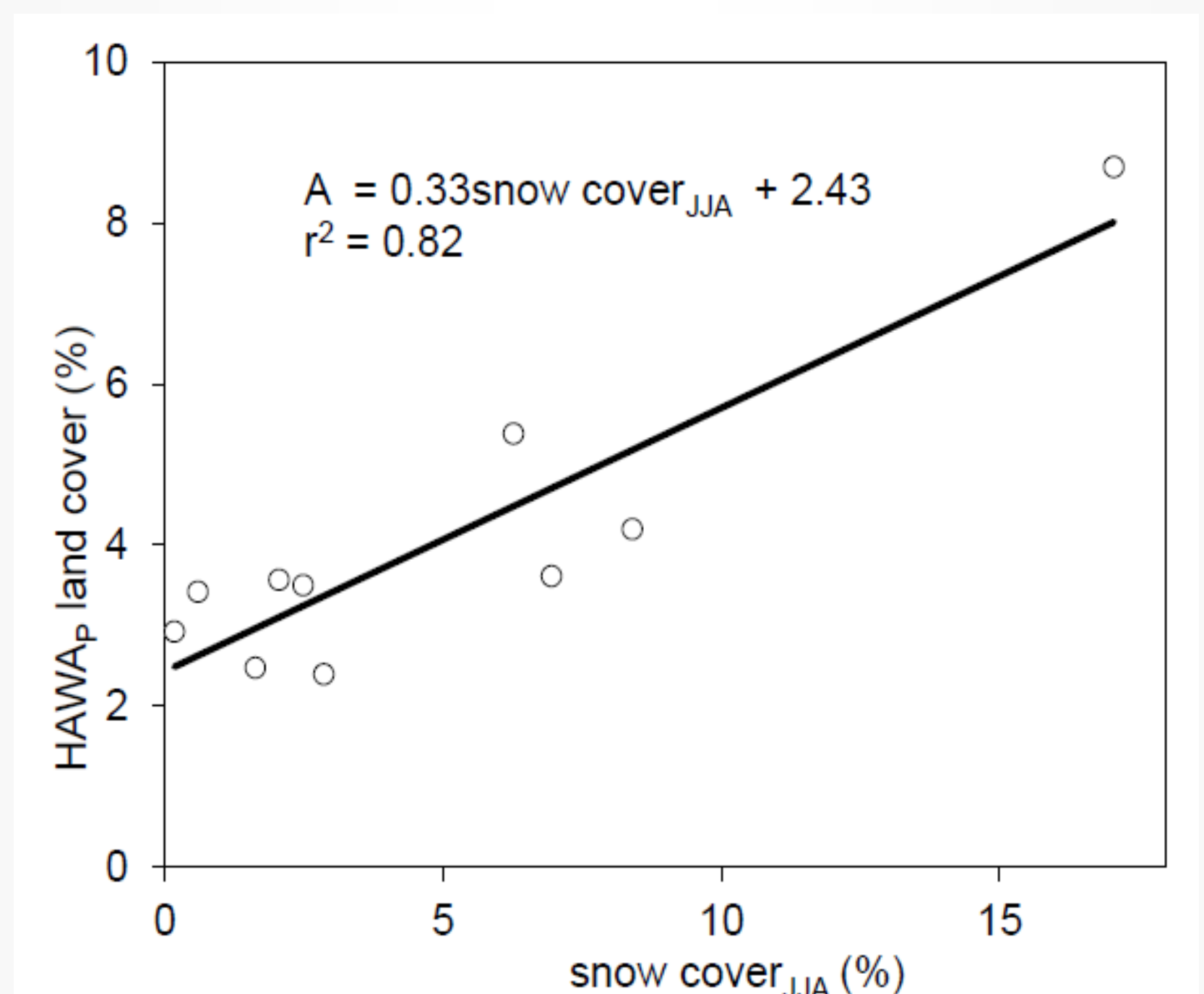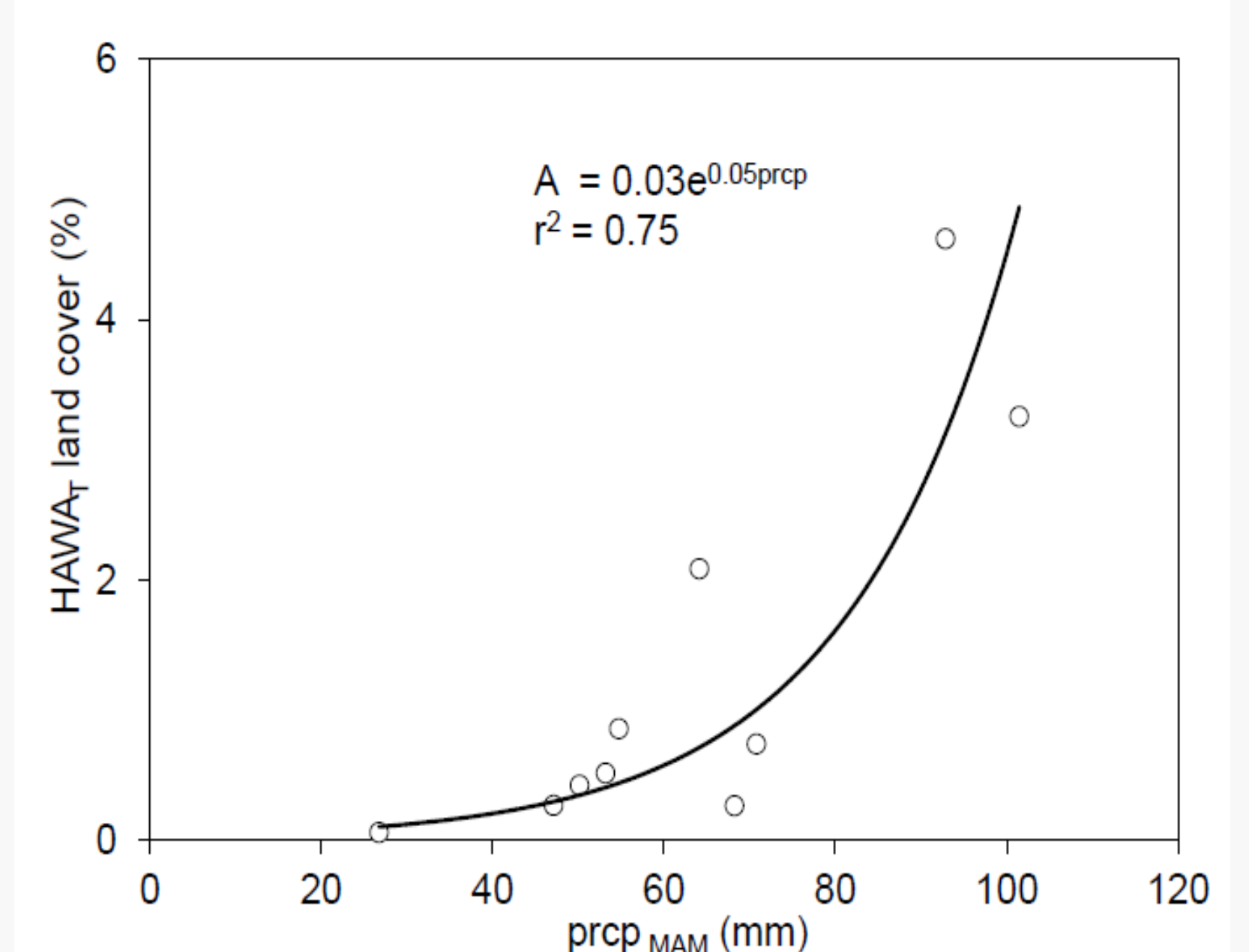Regression analyses of precipitation and HAWA subtype land cover

$$A = 0.03e^{0.05prcp}$$
$$r^2 = 0.75$$

$$A = 0.33\,\text{snow cover}_{JJA} + 2.43$$
$$r^2 = 0.82$$

Fig. 6: Relation between prcp$_{MAM}$ and HAWA$_T$ (top) and snowcover$_{JJA}$ and HAWA$_P$ (bottom) of 2000 to 2010.

Conclusions

The total extend of HAWA depends on precipitation during austral summer (MAM) and snow cover extend in austral winter (JJA). By measuring snow cover extend and applying a linear regression function it is possible to define maximum extend of HAWAp half a year in advance. It must be further evaluated if these finding can be concluded in other regions where HAWA occur and how this processes are connected to regional climates. Spatial gradients of HAWAp enable monitoring of annual plant water availability at a single HAWA site over the last decade. These findings need to be further investigated at selected HAWA sites to evaluate results from hydrologic models with in situ measurements and remote sensing. An important question is if the observed spatial changes have any consequences for the ecosystem functions usually related with wetlands, for example, water storage capacity, biomass production or provision of critical habitat features for flora and fauna of the semi-arid high Andes.

Reference: Otto, M., D. Scherer and J. Richters (2011): Hydrological differentiation and spatial distribution of high altitude wetlands in a semi-arid Andean region derived from satellite data, Hydrol. Earth Syst. Sci., 15, 1713-1727, doi:10.5194/hess-15-1713-2011.

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