



## UvA-DARE (Digital Academic Repository)

### Trait-based studies of páramo vegetation in the northern Andes

Cabrera Pantoja, M.J.

**Publication date**

2019

**Document Version**

Other version

**License**

Other

[Link to publication](#)

**Citation for published version (APA):**

Cabrera Pantoja, M. J. (2019). *Trait-based studies of páramo vegetation in the northern Andes*.

**General rights**

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

**Disclaimer/Complaints regulations**

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

---

## Bibliography

Abramoff MD, Magalhaes PJ and Ram SJ (2004) Image Processing with ImageJ. *Biophotonics International*, 11, 36–42.

Abreu Z, Llambí LD and Sarmiento L (2009) Sensitivity of soil restoration indicators during páramo succession in the high tropical Andes: chronosequence and permanent plot approaches. *Restoration Ecology*, 17, 619–628.

Akwood MO, Jurado E, Leishman M and Westoby M (1993) Geographic ranges of plant species in relation to dispersal morphology, growth form and diaspore weight. *Journal of Biogeography* 20, 563–571.

Albert CH, Thuiller W, Yoccoz NG, Douzet R, Aubert S and Lavorel S (2010a) A multi-trait approach reveals the structure and the relative importance of intra- vs. interspecific variability in plant traits. *Functional Ecology* 24, 1192–1201.

Albert CH, Thuiller W, Yoccoz NG, Soudant A, Boucher F, Saccone P and Lavorel S (2010b) Intraspecific functional variability: Extent, structure and sources of variation. *Journal of Ecology* 98, 604–613.

Albert CH, Grassein F, Schurr FM, Vieilledent G, and Violle C (2011) When and how should intraspecific variability be considered in trait-based plant ecology? *Perspectives in plant ecology. Evolution and Systematics* 13, 217–225.

Ali A, Xu MS, Zhao YT, Zhang QQ, Zhou LL, Yang XD and Yan ER (2015) Allometric biomass equations for shrub and small tree species in subtropical China. *Silva Fennica* 49, 1–10.

Almeida JP, Montúfar R and Anthelme F (2013) Patterns and origin of intraspecific functional variability in a tropical alpine species along an altitudinal gradient. *Plant Ecology and Diversity* 6, 423–433.

Alzate-Guarín F and Murillo-Serna JS (2016) Angiosperm flora on the páramos of north-western Colombia: diversity and affinities. *PhytoKeys* 70, 41–52.

Amaya-Espinel JD, Renjifo LM, Gómez MF, Amaya-Villarreal ÁM and Velásquez-Tibatá J (2011) Guía metodológica para el análisis de riesgo de extinción de especies en Colombia.

Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Pontificia Universidad Javeriana, 84 pp.

Andrade A, Medina MM, Shutze K and Ville J (2010) Ecosystem-based adaptation: lessons from the Chingaza Massif in the high mountain ecosystem of Colombia. In Andrade A, Herrera B and Cazzolla R (Eds.) Building resilience to climate change: ecosystem-based adaptation and lessons from the field. Gland, Switzerland, UICN. 21–32 pp.

Arellano-P H and Rangel-Ch J (2008) Patrones en la distribución de la vegetación en áreas de páramo de Colombia: heterogenidad y dependencia espacial. *Caldasia*, 30, 355–411.

Asner GP, Anderson CB, Martin RE, Knapp DE, Tupayachi R, Sinca F and Malhi Y (2014) Landscape-scale changes in forest structure and functional traits along an Andes-to-Amazon elevation gradient. *Biogeosciences*, 11, 843–856.

Auger S and Shipley B (2013) Inter-specific and intra-specific trait variation along short environmental gradients in an old-growth temperate forest. *Journal of Vegetation Science* 24, 419–428.

Ayala L, Villa M, Aguirre-Mendoza Z, Aguirre-Mendoza N (2014) Cuantificación del carbono en los páramos del parque nacional Yasuni, provincias de Loja y Zamora Chinchipe, Ecuador. *Revista Cedemaz* 4, 45–52.

Azócar A, Rada F and García-Núñez C (2007) Functional characteristics of the arborescent genus *Polylepis* along a latitudinal gradient in the high Andes. *Interciencia*, 32, 663–668.

Báez S, Cuesta F, Muriel P, Carrilla J, Jaramillo R, Irazábal J, Cuello S and Grau A (2014) Monitoreo de biodiversidad, productividad y experimentación en ecosistemas herbáceos andinos. Protocolo 4 - Versión 1. CONDESAN, Escuela de Ciencias Biológicas, Quito, Ecuador.

Barnola LG and Montilla MG (1997) Vertical distribution of mycorrhizal colonization, root hairs, and belowground biomass in three contrasting sites from the tropical high mountains, Mérida, Venezuela. *Arctic and Alpine Research*, 29, 206–212.

Baruch Z and Smith AP (1979) Morphological and physiological correlates of niche breadth in two species of *Espeletia* (Compositae) in the Venezuelan Andes. *Oecologia*, 82, 71–82.

Baskerville GL (1972) Use of logarithmic regression in the estimation of plant biomass. *Canadian Journal of Forestry*, 2, 49–53.

Bazzaz FA (1979) The physiological ecology of plant succession. *Annual Review of Ecology and Systematics*, 10, 351–371.

Beck E (1994) Cold tolerance. In: Rundel PW (ed) *Tropical Alpine Environments, Plant Form and Function*. Springer-Verlag, Berlin Heidelberg New York. 376 pp.

Becknell JM, Powers JS (2014) Stand age and soils as drivers of plant functional traits and aboveground biomass in secondary tropical dry forest. *Canadian Journal of Forestry*, 44, 604–613.

Beekman A and Verweij P (1987) Structure and nutrient status of a paramo bunchgrass vegetation in relation to soil and climate. M.Sc. thesis, University of Amsterdam, Amsterdam, The Netherlands.

Belluau M and Shipley B (2018) Linking hard and soft traits: physiology, morphology and anatomy interact to determine habitat affinities to soil water availability in herbaceous dicots. *PLoS ONE*, 13, 3, e0193130.

Berry PE and Calvo RN (1989) Wind Pollination, Self-Incompatibility, and Altitudinal Shifts in Pollination Systems in the High Andean genus *Espeletia* (Asteraceae). *American Journal of Botany*, 76, 1602–1614.

Billings WD (1974) Adaptations and Origins of Alpine Plants. *Arctic and Alpine Research*, 6, 129–142.

Blonder B, Kapas RE, Dalton RM, Graae BJ, Heiling JM and Opedal ØH (2018) Microenvironment and functional-trait context dependence predict alpine plant community dynamics. *Journal of Ecology*, 106, 1323–1337.

Bolnick DI, Svanbäck R, Fordyce JA, Yang LH, Davis JM, Hulsey CD and Forister ML (2003) The ecology of individuals: incidence and implications of individual specialization. *The American Naturalist*, 161, 1–28.

Bolnick DI, Amarasekare P, Araújo MS, Bürger R, Levine JM, Novak M . . . Vasseur DA (2011) Why intraspecific trait variation matters in community ecology. *Trends in Ecology and Evolution*, 26, 183–192.

Bonser SP (2006) From defining function: interpreting leaf functional variability in integrated plant phenotypes. *Oikos* 114, 187–190.

Bradley RS, Vuille M, Díaz HF and Vergara W (2006) Threats to water supplies in the tropical Andes. *Science*, 312, 1755–1756.

Bradshaw AD (1965) Evolutionary Significance of Phenotypic Plasticity in Plants. Editor(s): Caspari EW and Thoday JM. *Advances in Genetics*, Academic Press. Volume 13, pp 115–155.

Bremer L, Farley K, Chadwick O and Harden CP (2016) Changes in carbon storage with land management promoted by payment for ecosystem services. *Environmental Conservation*, 43, 397–406.

Brown JH (1984) On the Relationship between Abundance and Distribution of Species. *The American Naturalist*, 124, 255–279

Burnham, KP and Anderson DR (2002) Model selection and multimodel inference: a practical information-theoretic approach. Springer, New York, US. 488 pp.

Buytaert W, Wyseure G, de Bièvre B and Deckers J (2005) The effect of land-use changes on the hydrological behaviour of Histic Andosols in south Ecuador. *Hydrological Processes*, 19, 3985–3997.

Buytaert W, Célleri R, de Bièvre B, Cisneros F, Wyseure G, Deckers J. and Hofstede R (2006) Human impact on the hydrology of the Andean paramos. *Earth-Science Reviews*, 79, 53–72.

Cabrera M and Ramirez W (2014) Restauración ecológica de los páramos de Colombia: Transformación y herramientas para su conservación. Ministerio de Ambiente y Desarrollo Sostenible - Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogota, Colombia. pp 296.

Cabrera M, Samboni-Guerrero V and Duivenvoorden JF (2018) Non-destructive allometric estimates of above-ground and below-ground biomass of high-mountain vegetation in the Andes. *Applied Vegetation Science*. 21, 477–487.

Cáceres Y, Llambí LD and Rada F (2015) Shrubs as foundation species in a high tropical alpine ecosystem: a multi-scale analysis of plant spatial interactions. *Plant Ecology and Diversity*, 147–161.

Cadotte MW, Carscadden K and Mirotnick N (2011) Beyond species: Functional diversity and the maintenance of ecological processes and services. *Journal of Applied Ecology*, 48, 1079–1087.

Calviño CI, Fernández M and Martínez SG (2016) Las especies de Azorella (Azorelloideae, Apiaceae) con distribución extra-Argentina. *Darwiniana* 4, 57–82.

Cardozo-G H and Schnetter ML (1976) Estudios ecológicos en el Páramo de cruz verde, Colombia. III. La biomasa de tres asociaciones vegetales y la productividad de *Calamagrostis effusa* (H.B.K) Steud. y *Paepalanthus columbiensis* Ruhl. en comparación con la concentración de clorofila. *Caldasia*, 11, 69–83.

Carilla, J, Halloy S, Cuello S, Grau A, Malizia A and Cuesta F (2018) Vegetation trends over eleven years on mountain summits in NW Argentina. *Ecology and Evolution*, 8, 11554–11567.

Carlucci MB, Debastiani VJ, Pillar VD and Duarte LDS (2015) Between- and within-species trait variability and the assembly of sapling communities in forest patches. *Journal of Vegetation Science*, 26, 21–31.

Castellanos C (2013) Functional analysis of secondary tropical dry forest in a region of the Colombian caribbean. Thesis PhD dissertation. Bournemouth University. U.K. pp. 174.

Cavender-Bares J, Kozak KH, Fine PVA and Kembel SW (2009) The merging of community ecology and phylogenetic biology. *Ecology Letters*, 12, 693–715.

Célleri R (2009) Servicios ambientales para la conservación de recursos hídricos: lecciones aprendidas desde los Andes. Consortium for Sustainable Development of the Andean Ecoregion (CONDESAN), Lima, Perú.

Chacón-Madrigal E, Wanek W, Hietz P and Dullinger S (2018) Is local trait variation related to total range size of tropical trees? *PLoS One*, 13, 1–19.

Chalmandrier L, Münkemüller T, Colace M, Renaud J, Aubert S, Carlson BZ, Clément J, Legay N, Pellet G, Saillard A, Lavergne S and Thuiller W (2017) Spatial scale and intraspecific trait variability mediate assembly rules in alpine grasslands. *Journal of Ecology*, 105, 277–287

Chapin FSIII (1980) The mineral nutrition of wild plants. *Annual Review of Ecology and Systematics* 11, 233–260.

Chave J, Condit R, Aguilar S, Hernandez A, Lao S and Perez R (2004) Error propagation and scaling for tropical forest biomass estimates. *Philosophical Transactions of the Royal Society B* 359, 409–420.

Chave J, Andalo C, Brown S, Cairns M.A, Chambers JQ, Eamus D, Fölster H, Fromard F, Higuchi N, Kira T, Lescure JP, Nelson BW, Ogawa H, Puig H, Riéra B and Yamakura T (2005) Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145, 87–99.

Choler P (2005) Consistent shifts in spine plant traits along a mesotopographical gradient. *Arctic, Antarctic, and Alpine Research*, 37, 444–453.

Cianciaruso MV, Batalha MA, Gaston KJ and Petchey OL (2009) Including Intraspecific Variability in Functional Diversity. *Ecology*, 90, 81–89.

Cleef AM (1978) Characteristics of neotropical páramo vegetation and its subantarctic relations. *Forschung Erdwissenschaftliche*, 11, 365–390.

Cleef AM (1981) The vegetation of the páramos of the Colombian Cordillera Oriental. PhD Dissertation, University of Amsterdam, Amsterdam.

Cleef AM, Rangel-Ch JO, Salamanca S, Ariza-N C and Van Reenen GBA (2005) La vegetación del páramo del Macizo de Tatamá, Cordillera Occidental, Colombia. In: Van der Hammen T, Rangel-Ch, JO and Cleef AM (eds.): La Cordillera Occidental colombiana - Transecto de Tatamá. Studies on Tropical Andean Ecosystems, Estudios de Ecosistemas Tropandinos 6, pp. 377-468. Cramer, Borntraeger, Berlin-Stuttgart.

Coleman JS, McConnaughay KDM and Ackerly DD (1994) Interpreting phenotypic variation in plants. *Trends in Ecology and Evolution*, 9, 187-191.

Conti G and Díaz S (2013) Plant functional diversity and carbon storage – an empirical test in semi-arid forest ecosystems. *Journal of Ecology*, 101, 18-28.

Cornelissen JHC, Lavorel S, Garnier E, Díaz S, Buchmann N, Gurvich DE, Reich PB, ter Steege H, Morgan HD, van der Heijden MGA, Pausas, JG, Poorter H (2003) A handbook of protocols for standardized and easy measurement of plant functional traits worldwide. *Australian Journal Botany*, 51, 335-380.

Cuatrecasas J (1968) Páramo vegetation and its life forms. *Colloquium Geographicum*, 9, 163-186.

Cuello NLA and Cleef AM (2009) The páramo vegetation of Ramal de Guaramacal, Trujillo State, Venezuela. 1. Zonal communities. *Phytocoenologia*, 39, 295-329.

Cuesta F, Báez S, Muriel P and Salgado S (2014) La vegetación de los páramos del Ecuador. In: Cuesta F, Sevink J, Llambí LD, De Bièvre B and Posne J (eds.) Avances en investigación para la conservación de los páramos andinos. pp. 105-143. CONDESAN, Quito, Ecuador.

Cuesta F, Muriel P, Beck S, Meneses RI, Halloy S, Salgado S, Ortiz E and Becerra MT (2012) Biodiversidad y cambio climático en los Andes tropicales - conformación de una red de investigación para monitorear sus impactos y delinear acciones de adaptación. Red Gloria Andes, Quito, Ecuador.

Cuesta F, Muriel P, Llambí LD, Halloy S, Aguirre N, Beck S, Carilla J, Meneses RI, Cuello S, Grau A, Gómez L.E, Irazábal J, Jácome J, Jaramillo R, Ramírez L, Samaniego N, Suárez-Duque D, Thompson N, Tupayachi A, Viñas P, Yager K, Becerra MT, Pauli H and Gosling WD (2017) Latitudinal and altitudinal patterns of plant community diversity on mountain summits across the tropical Andes. *Ecography*, 40, 1381-1394.

Dahlgren R, Saigusa M and Ugolini FC (2004) The nature, properties and management of volcanic soils. *Advances in Agronomy*, 82, 113-182.

Dawson TP, Jackson ST, House JI, Prentice IC and Mace GM (2011) Beyond Predictions: Biodiversity Conservation in a Changing Climate. *Science*, 332, 53-58.

De la Riva EG, Pérez-Ramos IM, Tosto A, Navarro-Fernández CM, Olmo M, Marañón T and Villar R (2016) Disentangling the relative importance of species occurrence, abundance and intraspecific variability in community assembly: A trait-based approach at the whole-plant level in Mediterranean forests. *Oikos*, 125, 354-363.

Deldago A, Ruiz S, Arévalo L, Castillo G, Viles N, Calderón J, Cañizales J, Muñoz Y and Ramos R (2007) Plan de acción en biodiversidad del departamento de Nariño 2006-2030 - propuesta técnica. Corporación Autónoma Regional de Nariño - Corponariño, Pasto, Colombia.

Derroire G, Powers JS, Hulshof CM, Cárdenas VLE and Healey JR (2018) Contrasting patterns of leaf trait variation among and within species during tropical dry forest succession in Costa Rica. *Scientific Reports*, 8, 285.

Díaz S, Cabido M and Casanoves F (1998) Plant functional traits and environmental filters at a regional scale. *Journal of Vegetation Science*, 9, 113–122

Díaz S, Gurvich DE, Pérez N and Cabido M (2002) ¿Quién Necesita Tipos Funcionales de Plantas? *Boletín de la Sociedad Argentina de Botánica*, 37, 135–140.

Díaz S, Hodgson JG et al (2004) The plant traits that drive ecosystems: Evidence from three continents. *Journal of Vegetation Science*, 15, 295–304.

Díaz S, Lavorel S, de Bello, F, Quétier, F, Grigulis, K. and Robson T. M (2007) Incorporating plant functional diversity effects in ecosystem service assessments. *Proceedings of the National Academy of Sciences USA*, 104, 20684–20689.

Díaz S, Demissew S, Carabias J, Joloy C, Lonsdale M, Ash N, . . . Chan KM (2015) The IPBES Conceptual Framework — connecting nature and people. *Current Opinion in Environmental Sustainability*, 14, 1–16.

Díaz S, Kattge J, Cornelissen JHC, Wright IJ, Lavorel S, Dray S, Reu B, Kleyer M (...) and Gorné LD (2016) The global spectrum of plant form and function. *Nature*, 529, 167–171.

Diazgranados M and Barber JC (2017) Geography shapes the phylogeny of frailejones (*Espeletiinae* Cuatrec., *Asteraceae*): a remarkable example of recent rapid radiation in sky islands. *PeerJ*, 5: e2968.

Diemer M (1998a) Leaf lifespans of high-elevation, aseasonal Andean shrub species in relation to leaf traits and leaf habit. *Global Ecology and Biogeography Letters*, 7, 6, 457–465

Diemer M (1998b) Life span and dynamics of leaves of herbaceous perennials in high-elevation environments: ‘news from the elephant’s leg’. *Functional Ecology*, 12, 413–425.

Dorrepaal E (2007) Are plant growth-form-based classifications useful in predicting northern ecosystem carbon cycling feedbacks to climate change? *Journal of Ecology*, 95, 1167–1180.

Efron B and Tibshirani R (1993) *An Introduction to the Bootstrap*. Chapman and Hall, New York, US.

Egler FE (1952) Vegetation science concepts. I. Initial floristic composition, a factor in old-field vegetation development. *Vegetatio*, 4, 412–417.

Ensslin A, Rutten G, Pommer U, Zimmermann R, Hemp A and Fischer M (2015) Effects of elevation and land use on the biomass of trees, shrubs and herbs at Mount Kilimanjaro. *Ecosphere*, 6, 1–15.

Estrada A, Meireles C, Morales-Castilla I, Poschlod P, Vieites D, Araújo MB and Early R (2015) Life-history traits and geographical ranges. *Global Ecology and Biogeography*, 24, 849–858.

Farley KA and Bremer LL (2017) “Water Is Life”: Local Perceptions of Páramo Grasslands and Land Management Strategies Associated with Payment for Ecosystem Services. *Annals of the American Association of Geographers*, 107, 371–381.

Farley KA, Bremer LL, Harden CP and Hartsig J (2013) Changes in carbon storage under alternative land uses in biodiverse Andean grasslands: Implications for payment for ecosystem services. *Conservation Letters*, 6, 21–27.

Flombaum P and Sala OE (2007) A non-destructive and rapid method to estimate biomass and aboveground net primary production in arid environments. *Journal of Arid Environments*, 69, 352–358.

Flórez A (2002) Movilidad altitudinal de páramos y glaciares en los Andes colombianos. Congreso Mundial de Páramos, 1, 80–90. Retrieved from <http://www.banrepcultural.org/blaavirtual/geografia/congresoparamo/movilidad.pdf>.

Fushiki T (2011) Estimation of prediction error by using K-fold cross-validation. *Statistics and Computing* 21, 137–146.

Garnier E, Cortez J, Billès G, Navas M, Roumet C, Debussche M, Laurent G, Blanchard A, Aubry D, Bellmann A, Neill C, Toussaint J (2004) Plant functional markers capture ecosystem properties during secondary succession. *Ecology*, 85, 2630–2637.

Gastauer M and Meira-Neto JAA (2013) Avoiding inaccuracies in tree calibration and phylogenetic community analysis using Phylocom 4.2 *Ecological Informatics*, 15, 85–90.

Gaston KJ (1994) Measuring Geographic Range Sizes. *Oikos* 17, 198–205.

Gaston KJ (2011) *Common Ecology*. *BioScience* 61, 5, 354–362.

Gauch HG (1982) *Multivariate analysis in community ecology*. Cambridge University Press, Cambridge.

Gaudet CL and Keddy PA (1988) A comparative approach to predicting competitive ability from plant traits. *Nature*, 334, 242–243.

GBIF.ORG (2017-2018) GBIF Occurrence Download <https://doi.org/10.15468/dl.jtvqhw>

Geng Y, Wang Z, Liang C, Fang J, Baumann F, Kühn P, Scholten T and He J (2012) Effect of geographical range size on plant functional traits and the relationships between plant, soil and climate in Chinese grasslands. *Global Ecology and Biogeography*, 21, 416–427.

Gibbon A, Silman MR, Malhi Y, Fisher JB, Meir P, Zimmermann M, Dargie GC, Farfan WR, Garcia KC (2010) Ecosystem carbon storage across the grassland-forest transition in the high Andes of Manu National Park, Peru. *Ecosystems*, 13, 1097–1111.

Gitay H and Noble IR (1997) What are plant functional types and how should we seek them? In: Smith TM, Shugart HH. and Woodward FI (eds.) *Plant functional types*, pp. 3–19. Cambridge University Press, Cambridge

Givnish TJ (1987) Comparative studies of leaf form: assessing the relative roles of selective pressures and phylogenetic constraints. *New Phytologist*, 106, 131–160.

Glozer K (2008) Protocol for leaf Image analysis – surface area. Dept. of Plant Science. University of California. Davis, CA, pp. 1–8.

Gondard H and Deconchat M (2003) Effects of soil surface disturbances after logging on plant functional types. *Annals of Forest Science*, 60, 725–732.

González-Carranza Z, Hooghiemstra H and Vélez MI (2012) Major altitudinal shifts in Andean vegetation on the Amazonian flank show temporary loss of biota in the Holocene. *Holocene*, 22, 1227–1241.

Grace JB (2008) Structural Equation Modeling for observational studies. *J Wildlife Manage*, 72, 14–22.

Gregory-Wodzicki KM (2000) Uplift history of the Central and Northern Andes: A review. *Geological Society of America Bulletin*, 112, 1091–1105.



Grime JP (1979) *Plant strategies and vegetation processes*. Chichester, UK: John Wiley and Sons.

Grime JP (1998) Benefits of plant diversity to ecosystems: immediate, filter and founder effects. *Journal of Ecology*, 86, 902–910.

Guevara JC, Gonnet JM and Estevez OR (2002) Biomass estimation for native perennial grasses in the plain of Mendoza, Argentina. *Journal of Arid Environments*, 50, 613–619.

Harden CP, Hartsig J, Farley KA, Lee J and Bremer LL (2013) Effects of land-use change on water in Andean Páramo grassland soils. *Annals of the Association of American Geographers*, 103, 375–384.

Hedberg I and Hedberg O (1979) Tropical-alpine life-forms of vascular plants. *Oikos*, 33, 297–307.

Hedberg O (1964) Features of Afroalpine Plant Ecology. *Acta Phytogeographica Suecica*, 49, 150.

Henry GHR and Molau U (1997) Tundra plants and climate change: the International Tundra Experiment (ITEX). *Global Change Biology*, 3, 1–9.

Herbario JBB (2018) Jardín Botánico de Bogotá José Celestino Mutis. Disponible en: <http://colecciones.jbb.gov.co/herbario>. Consultado en 2018.

Hernández Z (2005) Modelos arquitectónicos en humedales andinos: Un abanico de respuestas funcionales. Postgrado en Ecología Tropical. Instituto de Ciencias Ambientales y Ecológicas (ICAE). Universidad de Los Andes. Mérida, Venezuela.

Hervé D (1994) Respuestas de los componentes de la fertilidad del suelo a la duración del descanso. In D. Hervé, D. Genin and G. Rivière (Eds.) *Dinámicas del descanso de la tierra en los Andes* (pp. 155–169). La Paz, Bolivia: IBTA-ORSTOM.

Hnatiuk RJ (1978) The growth of tussock grasses on an equatorial high mountain and on two sub-antarctic islands. In: Troll, C. and Lauer, C (eds.) *Geoecological relations between the southern temperate zone and the tropical mountains*. pp. 159–190. Steiner, Wiesbaden, Germany.

Hofstede R (1995) Effects of burning and grazing on a Colombian Páramo Ecosystem. The Netherlands.

Hofstede R, Mondragon MX and Rocha CM (1995) Biomass of grazed, burned and undisturbed paramo grasslands, Colombia. I. Aboveground vegetation. *Arctic and Alpine Research*, 27, 1–12.

Hofstede R, Segarra P and Mena P (2003) *Los paramos del mundo*. Quito, Ecuador: Proyecto Atlas Mundial de los Paramos.

Hofstede R, Calles J, López V, Polanco R, Torres F, Ulloa J, Vásquez A and Cerra M (2014) Los páramos Andinos ¿Qué sabemos? Estado de conocimiento sobre el impacto del cambio climático en el ecosistema páramo. UICN, Quito, Ecuador.

Holling CS (1996) Engineering resilience versus ecological resilience. In *Engineering within ecological constraints*. Schulze P (ed.). National Academy, Washington. pp. 31–44.

Hooper DU, Solan M, Symstad A, Díaz S, Gessner MO, Buchman N, Degrange V, Grime P, Hulot F, Mermillod F, Roy J, Spehn E and van Peer L (2002) Species diversity, functional diversity,

and ecosystem functioning. In: Loreau M, Naeem S, and Inchausti P (eds.) Biodiversity and ecosystem functioning. Oxford University Press, Oxford. pp. 195-208.

Hoorn C, Wesselingh F, ter Steege H, Bermudez M, Mora A, Sevenik J, (et al.) Antonelli A (2010) Amazonia through time: Andean uplift, climate change, landscape evolution and biodiversity. *Science*, 330, 927-931.

Hughes C and Eastwood R (2006) Island radiation on a continental scale: exceptional rates of plant diversification after uplift of the Andes. *Proceedings of the National Academy of Sciences USA*, 103, 10334-10339.

Huston M and Smith T (1987) Plant succession: life history and competition. *The American Naturalist*, 130, 168-198.

IGAC (1990) Métodos analíticos del laboratorio de suelos. Bogotá, Colombia: Instituto Geográfico "Agustín Codazzi".

Jaimes V and Sarmiento L (2002) Regeneración de la vegetación de páramo después de un disturbio agrícola en la cordillera oriental de Colombia. *Ecotropicos*, 15, 61-74.

James G, Witten D, Hastie T and Tibshirani R (2013) An introduction to statistical learning: with applications in R. Springer, New York.

Johnson PS, Johnson CL and West NE (1988) Estimation of phytomass for ungrazed crested wheatgrass plants using allometric equations. *Journal of Range Management*, 41, 421-425.

Jung V, Albert CH, Violle C, Kunstler G, Loucougaray G and Spiegelberger T (2014) Intraspecific trait variability mediates the response of subalpine grassland communities to extreme drought events. *Journal of Ecology*, 102, 45-53.

Jung V, Violle C, Mondy C, Hoffmann L and Muller S (2010) Intraspecific variability and trait-based community assembly. *Journal of Ecology*, 98, 1134-1140

Keddy P (1992) Assembly and response rules - two goals for predictive community ecology. *Journal of Vegetation Science*, 3, 157-164.

Kerkhoff AJ and Enquist BJ (2006) Ecosystem allometry: the scaling of nutrient stocks and primary productivity across plant communities. *Ecology Letters*, 9, 419-427.

Kichenin E, Wardle DA, Duane A, Peltzer DA, Morse CW and Freschet GT (2013) Contrasting effects of plant inter- and intraspecific variation on community-level trait measures along an environmental gradient. *Functional Ecology*, 27, 1254-1261.

Körner C (1995) Alpine Plant Diversity: A Global Survey and Functional Interpretations. In: Chapin FS, Körner C (eds) Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences. Ecological Studies (Analysis and Synthesis). 113. Springer, Berlin, Heidelberg, pp 45-62.

Körner C (1999) Alpine plant life: functional plant ecology of high mountain ecosystems. Berlin, Germany: Springer.

Körner C (2003) Alpine plant life. Springer, Berlin, Germany.

Kudernatsch T, Fischer A, Bernhardt-Romermann M and Abs C (2008) Short-term effects of temperature enhancement on growth and reproduction of alpine grassland species. *Basic Applied Ecology*, 9, 263-274.

Kunin WE and Gaston KJ (1993) The biology of rarity: Patterns, causes and consequences. *Trends in Ecology and Evolution*, 8, 298-301.

Laliberté E, Tylianakis JM (2012) Cascading effects of long-term land-use changes on plant traits and ecosystem functioning. *Ecology*, 93, 145–155.

Lambers H and Poorter H (1992) Inherent variation in growth rate between higher plants: A search for physiological causes and ecological consequences. *Advances in Ecological Research*, 23, 187–261.

Lambers H, Chapin FS, Pons TL (2008) *Plant physiological ecology*. Springer, New York.

Lavorel S and Garnier E (2002) Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. *Functional Ecology*, 16, 545–556.

Lavorel S and Grigulis K (2012), How fundamental plant functional trait relationships scale-up to trade-offs and synergies in ecosystem services. *Journal of Ecology*, 100, 128–140.

Lavorel S, McIntyre S, Landsberg J and Forbes TDA (1997) Plant functional classifications: from general groups to specific groups based on response to disturbance. *TREE*, 12, 474–478.

Lawton JH (1999) Are There General Laws in Ecology? *Oikos*, 84, 177–192.

Legendre P and Gallagher ED (2001) Ecologically meaningful transformations for ordination of species data. *Oecologia*, 129, 271–280.

Legendre P and Legendre L (1998) *Numerical ecology*. Amsterdam, The Netherlands: Elsevier.

Leps J, deBello F, Smilauer P, Dolezal J (2011) Community trait response to environment: disentangling species turnover vs intraspecific trait variability effects. *Ecography*, 34, 856–863.

Li H, Yu K, Ratajczak Z, Nippert JB, Tondrob D, Xu D, Li W and Du G (2016) When variability outperforms the mean: trait plasticity predicts plant cover and biomass in an alpine wetland. *Plant and Soil*, 407, 401–415.

Liu M, Liu G, Gong L, Wang D and Sun J (2014) Relationships of biomass with environmental factors in the grassland area of Hulunbuir China. *PLoS One*, 9, 3–10.

Llambí LD and Sarmiento L (1998) Biomasa microbiana y otros parámetros edáficos en una sucesión secundaria de los páramos venezolanos. *Ecotropicos*, 11, 1–14.

Llambí LD, Fontaine M, Rada F, Saugier B and Sarmiento L (2003) Ecophysiology of dominant species during old field succession in a High Tropical Andean Ecosystem. *Arctic, Antarctic, and Alpine Research*, 3, 447–453.

Llambí LD, Sarmiento L and Rada F (2013) La evolución de la investigación ecológica en los páramos de Venezuela: múltiples visiones de un ecosistema único. In Medina E, Huber O, Nassar J and Navarro P (eds.), *Recorriendo el pasiaje vegetal de Venezuela*. Caracas, Ediciones IVIC, Instituto Venezolano de Investigaciones Científicas, pp. 173–209.

Londoño C, Cleef AM and Madriñan C (2014) Angiosperm flora and biogeography of the páramo region of Colombia, Northern Andes. *Flora*, 209, 81–87.

Lozano P, Cleef AM and Bussmann RW (2009) Phytogeography of the vascular páramo flora of Podocarpus National Park, south Ecuador. *Arnaldoa*, 16, 69–85.

Luo YH, Liu J, Tan SL, Cadotte MW, Wang YH, Xu K, Li DZ and Gao LM (2016) Trait-based community assembly along an elevational gradient in subalpine forests: Quantifying the roles of environmental factors in inter- and intraspecific variability. *PLoS One*, 11, 1–20.

Lusk CH and Warton DI (2007) Global meta-analysis shows that relationships of leaf mass per area with species shade tolerance depend on leaf habit and ontogeny. *New Phytologist*, 176, 764–774.

Luteyn JL (1992) Páramos: Why study them? In: Balslev H and Luteyn JL (eds.) *Páramo, an Andean ecosystem under human influence*, pp. 1–14. Academic Press, London, UK.

Luteyn JL (1999) Introduction to the páramo ecosystem. In: Luteyn JL (Ed.), *Páramos: a checklist of plant diversity, geographical distribution, and botanical literature*. The New York Botanical Garden Press, New York, pp. 1–40.

Lutz R and Vader P (1987) Biomass, productivity and nutrient status in a Colombian bunch-grass paramo. M.Sc. thesis, University of Amsterdam, Amsterdam, The Netherlands.

Ma W, Yang Y, He J, Zeng H and Fang J (2008) Above- and belowground biomass in relation to environmental factors in temperate grasslands, Inner Mongolia. *Science in China, Series C: Life Sciences* 51, 263–270.

MADS (2015) Plan Nacional de Restauración. Ministerio de Ambiente y Desarrollo Sostenible, Bogotá, Colombia.

Malagón D. and Pulido C (2000) Suelos del Páramo Colombiano. In: Rangel, O (Ed.). *Colombia Diversidad Biótica III. La Región de Vida Paramuna*. Universidad Nacional de Colombia. Facultad de Ciencias. Instituto de Ciencias Naturales. Bogotá, Colombia. pp. 37-84.

Maracahipes L, Carlucci MB, Lenza E, Marimon BS, Marimon BH, Guimarães FAG and Cianciaruso MV (2018) How to live in contrasting habitats? Acquisitive and conservative strategies emerge at inter- and intraspecific levels in savanna and forest woody plants. *Perspectives in Plant Ecology, Evolution and Systematics*, 34, 17–25.

McCune B and Grace JB (2002) *Analysis of Ecological Communities*. MjM Software, Glenden Beach, US.

McGill BJ, Enquist BJ, Weiher E and Westoby M (2006) Rebuilding community ecology from functional traits. *Trends in Ecology and Evolution*, 21, 178-185.

MEA - Millennium Ecosystem Assessment (Program) (2002) *Ecosystems and human well-being*. Washington D.C.: Island Press

Minaya V, Corzo G, Romero-Saltos H, van der Kwast J, Lantinga E, Galárraga-Sánchez R and Mynett A (2016) Altitudinal analysis of carbon stocks in the Antisana páramo, Ecuadorian Andes. *Journal of Plant Ecology*, 9, 553–563.

Minchin PR (1987) An evaluation of relative robustness of techniques for ecological ordinations. *Vegetatio*, 69, 89–107.

Moles AT, Warton DI, Warman L, Swenson NG, Laffan SW, Zanne AE, Pitman A, Hemmings FA and Leishman MR (2009) Global patterns in plant height. *Journal of Ecology*, 97, 923–932.

Molina A, Govers G, Vanacker V, Poesen J, Zeelmaekers E and Cisneros F (2007) Runoff generation in a degraded Andean ecosystem: Interaction of vegetation cover and land use. *Catena*, 71, 357–370.

Monasterio M and Molinillo M (2003) Venezuela. El Paisaje y su Diversidad. In R. Hofstede P. Segarra and P. Mena (Eds.). *Los páramos del mundo. Atlas mundial de los paramos* (pp. 205-236). Quito, Ecuador: Global Peatland Initiative/NC-IUCN/EcoCiencia.

Monasterio M (1980) Estudios ecológicos en los páramos andinos. Ediciones de la Universidad de los Andes, Mérida.

Monteiro JAF, Hiltbrunner E and Körner C (2011) Functional morphology and microclimate of *Festuca orthophylla*, the dominant tall tussock grass in the Andean Altiplano. *Flora: Morphology, Distribution, Functional Ecology of Plants*, 206, 387–396.

Montilla M, Monasterio M and Sarmiento L (2002) Dinámica sucesional de la fitomasa y los nutrientes en parcelas en sucesión-regeneración en un agroecosistema de páramo. *Ecotropicos*, 15, 75–84.

Mora-Osejo L and Sturm H (eds.) (1994) Estudios Ecologicos del páramo y del bosque altoandino cordillera oriental de Colombia Tomo II. Santafe de Bogotá, D.C., Academia Colombiana de Ciencias Exactas, Fisicas y Naturales. Coleccion Jorge Alvarez Lleras No.6, p. 715

Morales M, Otero J, Van der Hammen T, Torres A, Cadena C, Pedraza C, Rodríguez N, Franco C, Betancourth JC, Olaya E, Posada E, Cárdenas L (2007) Atlas de páramos de Colombia. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Bogotá.

Moreno C and Mora-Osejo L (1994) Estudios de los agroecosistemas de la región de Sabaneque (Municipio de Tusa, Cundinamarca) y algunos de sus efectos sobre la vegetación y el suelo. In Mora-Osejo L and Sturm H (Eds.) Estudios ecológicos del páramo y del bosque alto-andino Cordillera Oriental de Colombia, tomo II. Bogotá, Colombia: Academia Colombiana de Ciencias Exactas, Físicas y Naturales, Colección Jorge Alvarez Lleras, no. 6. pp. 563–581

Moscol-Olivera M and Cleef AM (2009) A phytosociological study of the páramo along two altitudinal transects in El Carchi province, northern Ecuador. *Phytocoenologia*, 39, 79–107.

Muller CH (1952) Plant succession in arctic heath and tundra in northern Scandinavia. *Bulletin of the Torrey Botanical Club*, 79, 296–309.

Mulligan M, Rubiano J, Hyman G, White D, García J, Saravia M, . . . Saenz-Cruz L (2010) The Andes basins: biophysical and developmental diversity in a climate of change. *Water International*, 35, 472–492.

Münkemüller T, Lavergne S, Bzeznik B, Dray S, Jombart T, Schiffers K and Thuiller W (2012) How to measure and test phylogenetic signal. *Methods in Ecology and Evolution*, 3, 743–756.

Murray BR, Thrall PH, Gill AM and Nicotra AB (2002) How plant life-history and ecological traits relate to species rarity and commonness at varying spatial scales. *Austral Ecology*, 27, 291–310.

Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB and Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature*, 403, 853–858.

Nafus AM, McClaran MP, Archer SR and Throop HL (2009) Multispecies allometric models predict grass biomass in semidesert rangeland. *Rangeland Ecology and Management*, 62, 68–72.

Nie X, Yang Y, Yang L and Zhou G (2016) Above- and belowground biomass allocation in shrub biomes across the Northeast Tibetan Plateau. *PloS One*, 11, e0154251.

Niklas KJ (2005) Modelling below- and above-ground biomass for non-woody and woody plants. *Annals of Botany*, 95, 315–321.

Noble IR and Slatyer RO (1980) The use of vital attributes to predicts successional changes in plant communities subject to recurrent disturbances. *Vegetatio*, 43, 5–21

Ochoa-Tocachi BF, Buytaert W, De Bièvre B, Célleri R, Crespo P, Villacís M, Llerena CA, Acosta L, Villazón M, Gualpa M, Gil-Ríos J, Fuentes P, Olaya D, Viñas P, Rojas G and Arias S (2016) Impacts of land use on the hydrological response of tropical Andean catchments. *Hydrological Processes*, 30, 4074–4089.

Oksanen J, Blanchet FG, Friendly M, Kindt R, Legendre P, McGlinn D, Minchin P, O'Hara RB, Simpson GL, Solymos P, Stevens MHM, Szoecs E, Wagner H (2017) *Vegan: Community Ecology Package*. R package version 2.4-2. <https://CRAN.R-project.org/package=vegan>.

Oliveras I, Girardin C, Doughty CE, Cahuana N, Arenas CE, Oliver V, Huasco WH and Malhi Y (2014) Andean grasslands are as productive as tropical cloud forests. *Environmental Research Letters*, 9, 115011.

Oliveras I, Van der Eynden M, Malhi Y, Cahuana N, Menor C, Zamora F and Haugaasen T (2014) Grass allometry and estimation of above-ground biomass in tropical alpine tussock grasslands. *Austral Ecology*, 39, 408–415.

Pagel MD (1992) A method for the analysis of comparative data. *Journal of Theoretical Biology*, 156, 431–442.

Patty L, Halloy SRP, Hiltbrunner E and Körner C (2010) Biomass allocation in herbaceous plants under grazing impact in the high semi-arid Andes. *Flora*, 205, 695–703.

Pedraza-Peñalosa P, Betancur J and Franco-Rosselli P (2004) Chisacá, un recorrido por los páramos andinos. Universidad Nacional de Colombia - Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, Colombia.

Pérez CA and Frangi JL (2000) Grassland biomass dynamics along an altitudinal gradient in the Pampa. *Journal of Range Management*, 53, 518–528.

Peterson GD, Allen CR and Holling CS (1998) Ecological resilience, biodiversity, and scale. *Ecosystems*, 1, 6–18.

Peyre G, Balslev H and Font X (2018) Phytoregionalisation of the Andean páramo. *PeerJ* 6, 1–27.

Pickett STA, Collins SL and Armesto JJ (1987) Models, mechanisms and pathways of succession. *Botanical Review*, 53, 335–371.

Piñeiro G, Perelman S, Guerschman JP and Paruelo JM (2008) How to evaluate models: observed vs. predicted or predicted vs. observed? *Ecological Modelling*, 216, 316–322.

Plunkett GM and Nicolas AN (2017) Assessing *Azorella* (Apiaceae) and its allies: Phylogenetics and a new classification. *Brittonia*, 69, 31–61.

Podwojewsky P and Poulénard J (2005) Paramos soils. *Encyclopedia of Soil Science*, 1239–1242.

Poorter H and Garnier E (1999) Ecological significance of inherent variation in relative growth and its components. In: *Handbook of functional ecology*, Pugnaire FI and Valladares F, eds. Marcel Dekker, New York, 81–120 pp.

Poorter H, Niinemets Ü, Poorter L, Wright IJ and Villar R (2009) Causes and consequences of variation in leaf mass per area (LMA): a meta-analysis. *New Phytologist*, 182, 656–688.

Pucheta E, Cabido M, Díaz S and Funes G (1998) Floristic composition, biomass, and aboveground net plant production in grazed and protected sites in a mountain grassland of central Argentina. *Acta Oecologia*, 19, 97–105.

R Core Team (2017) R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <https://www.R-project.org/>

R Development Core Team (2018) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0.

Ramírez W, Aguilar-Garavito M, Calle Z and Cabrera M (2015) Introducción al monitoreo en la restauración. In: Aguilar-Garavito M and Ramírez W (eds.) Monitoreo a procesos de restauración ecológica, aplicado a ecosistemas terrestres. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH). Bogotá D.C, Colombia. 250 pp.

Ramsay PM and Oxley ERB (1997) The growth form composition of plant communities in the ecuadorian páramos. *Plant Ecology*, 131,173–192.

Ramsay PM and Oxley ERB (2001) An assessment of aboveground net primary productivity in Andean grasslands of central Ecuador. *Mountain Research and Development*, 21, 161–167.

Rangel-Ch J (2018) Colombia biodiversidad biótica XVI. Patrones de riqueza y de diversidad de las plantas con flores en el bioma de páramo ( Rangel-Ch J. Ed.) (Primera ed). Bogota D.C, Universidad Nacional de Colombia. Facultad de Ciencias, Insituto de Ciencias Naturales, 386 pp.

Rangel-Ch JO and Sánchez D (2005) La flora del páramo de Frontino. In: Van der Hammen T, Rangel-Ch JO and Cleef AM (eds.): La Cordillera Occidental colombiana - Transecto de Tatamá. *Studies on Tropical Andean Ecosystems / Estudios de Ecosistemas Tropandinos* 6, pp. 833-858. Cramer/Borntraeger, Berlin-Stuttgart.

Rangel-Ch JO, Rivera O and Cleef AM (2008) Flora vascular del macizo Sumapaz. In: Van der Hammen T (ed.) with Rangel-Ch JO and Cleef AM. La Cordillera Oriental Colombiana – Transecto Sumapaz. *Estudios de ecosistemas tropandinos* 7. J. Cramer, Berlin, Stuttgart. 203-210 pp.

Rangel-Ch JO (ed.) (2000) Colombia Diversidad Biótica III, La región paramuna de Colombia. Unibiblos, Universidad Nacional de Colombia, Bogotá.

Raunkiaer C (1934) The life forms of plants and statistical plant geography. Oxford University Press, London.

Reich PB, Walters MB and Ellsworth DS (1992) Leaf life-span in relation to leaf, plant, and stand characteristics among diverse ecosystems. *Ecological Monographs*, 62, 365-392.

Reich PB, Walters MB and Ellsworth DS (1997) From tropics to tundra: Global convergence in plant functioning. *Proceedings of the National Academy of Sciences (USA)* 94, 13730-13737.

Reich PB, Ellsworth DS, Walters MB, Vose J, Gresham C, Volin J and Bowman W (1999) Generality of leaf traits relationships: a test across six biomes. *Ecology*, 80, 1955-1969.

Reich PB, Wright IJ, Cavender-Bares J, Craine JM, Oleksyn J, Westoby M and Walters MB (2003) The evolution of plant functional variation: traits, spectra, and strategies. *International Journal of Plant Sciences*, 164, S143–S164 ST–The evolution of plant functional.

Revell LJ (2010) Phylogenetic signal and linear regression on species data. *Methods, Ecology and Evolution*, 1, 319–329.

Revell LJ (2017) Package ‘phytools’. V 0.6-60. Phylogenetic tools for comparative biology (and other things). CRAN.

Rocha CM and Mondragon MX (1994) Efectos de la quema y del pastoreo sobre la biomasa y sobre la producción de la vegetación paramuna. B.Sc. thesis, Fundación Universitaria de Popayán, Popayán, Colombia.

Rolleri CH and Prada C (2006) Catálogo comentado de las especies de *Blechnum* L. de Mesoamérica y Sudamérica. Anales del Jardín Botánico de Madrid, 63, 67–106.

Rossenaar AJGA and Hofstede RGM (1992) Effects of burning and grazing on root biomass in the páramo ecosystem. In: Balslev H and Luteyn JL (eds.) Páramo: an Andean ecosystem under human influence. Academic Press, London, UK. 211–213 pp.

Rull V (2014) Biodiversity, Mountains and Climate Change. *Collectanea Botanica*, 33, 1–5.

Ryser P and Urbas P (2000) Ecological significance of leaf life span among Central European grass species. *Oikos*, 91, 41–50.

Sande MT, Peña-Claros M, Ascarrunz N, Arets EJ, Licona JC, Toledo M and Poorter L (2017) Abiotic and biotic drivers of biomass change in a Neotropical forest. *Journal of Ecology*, 105, 1223–1234.

Sarmiento G (1986) Ecologically crucial features of climate in high tropical mountains. In: Vuillemier F and Monasterio M (eds.), High altitude tropical biogeography. Oxford Univ.Press, 11–45 pp.

Sarmiento L and Bottner P (2002) Carbon and nitrogen dynamics in two soils with different fallow times in the high tropical Andes: indications for fertility restoration. *Applied Soil Ecology*, 19, 79–89.

Sarmiento L (2006) Grazing impact on vegetation structure and plant species richness in an old-field succession of the Venezuelan Páramos. In: Spehn E.M, Liberman M, Körner C (Eds.) Land use change and mountain biodiversity. CRC Press, Boca Raton, 119–135 pp.

Sarmiento L, Llambí LD, Escalona A and Marquez N (2003) Vegetation patterns, regenerating rates and divergence in al old-field succession of the high tropical Andes. *Plant Ecology*, 166, 63–74.

Schneider CA, Rasband WS and Eliceiri KW (2012) NIH Image to ImageJ: 25 years of image analysis. *Nature methods*, 9, 671–675.

Scurlock JMO and Hall DO (1998) The global carbon sink: a grassland perspective. *Global Change Biology* 4, 229–233.

SDA-Secretaría Distrital De Ambiente (2010) Diagnóstico de las áreas rurales de Bogotá, D.C. Tomo III. Área rural Localidad de Santa Fe (UPR Cerros Orientales). Convenio Interadministrativo de Cooperación 017 de 2009 y 234 de 2009, suscrito entre la Secretaría Distrital de Planeación Secretaría Distrital de Ambiente, Unidad Administrativa Especial de Servicios Públicos, Secretaría Distrital de Hábitat y Universidad Distrital “Francisco José de Caldas”. Bogotá, D.C. 409 pp.

Shiple B (2006) Net assimilation rate, specific leaf area and leaf mass ratio: which is most closely related with relative growth rate? A meat-analysis. *Functional Ecology*, 20, 565–574.

Shiple B (2000) A new inferential test for path models based on directed acyclic graphs. *Struct Equ Modeling*, 7, 206–218.

Shiple B (2009) Confirmatory path analysis in a generalized multilevel context. *Ecology*, 90, 363–368.



Shipley B (2016) Cause and correlation in biology, 2nd edn. Cambridge University Press, Cambridge.

Shoji SM, Nanzyo M, Dahlgren R.A (1993) Volcanic ash soils: genesis, properties and utilization. Elsevier, Amsterdam.

Sides CB, Enquist BJ, Ebersole JJ, Smith MN, Henderson AN and Sloat LL (2014) Revisiting Darwin's hypothesis: Does greater intraspecific variability increase species ecological breadth? *American Journal of Botany*, 101, 56–62.

Siefert A, Fridley JD, Ritchie ME (2014) Community functional responses to soil and climate at multiple spatial scales: when does intraspecific variation matter? *PLOS ONE*, 9, e11189.

Siefert A, Violle C, Chalmandrier L, Albert CH, Taudiere A, Fajardo A, (et al.) Wardle DA (2015) A global meta-analysis of the relative extent of intraspecific trait variation in plant communities. *Ecology Letters*.

Sierra-Escobar A and Mora-Osejo L (1994) Estudio morfológico del sistema radical de plantas del páramo y del bosque altoandino. In: Mora-Osejo L and Sturm H (eds.) *Estudios ecologicos del paramo y del bosque altoandino cordillera oriental de Colombia*, Tomo II. p. 715. Academia Colombiana de Ciencias Exactas, Físicas y Naturales, Bogotá, Colombia.

Sileshi GW (2014) A critical review of forest biomass estimation models, common mistakes and corrective measures. *Forest Ecology and Management* 329, 237–254.

Simpson BB (1975) Pleistocene Changes in the Flora of the High Tropical Andes. *Paleobiology*, 1, 273–294.

Simpson BB (1983) An Historical Phytogeography of the High Andean Flora. *Revista Chilena de Historia Natural*, 56, 109–122.

Sklenář P and Ramsay P (2001) Diversity of zonal paramo plant communities in Ecuador. *Diversity and Distributions*, 7, 113–124.

Smith AP (1972) Notes on wind-related growth patterns of paramo plants in Venezuela. *Biotropica*, 4, 1–16.

Smith AP and Young T (1987) Tropical Alpine Plant Ecology. *Annals Review Ecology and Systematic*, 18, 137–158.

Smith JM and Cleef AM (1988) Composition and origins of the world's tropicalpine floras. *Journal of Biogeography*, 15, 631–645.

Smith JM and Klinger LF (1985) Aboveground: belowground phytomass ratios in Venezuelan paramo vegetation and their significance. *Arctic and Alpine Research*, 17, 189–198.

Sokal RR and Rohlf FJ (1995) *Biometry*, third edition. Freeman, New York.

Solarte-Cruz ME, Narváez-Bravo G, Rivas G, Baca AE, Muñoz D, Calderón JJ, Torres C, Figueroa V and Rengifo J (2007) Proyecto estado del arte de la información biofísica y socioeconómica de los páramos de Nariño, Tomo II. Características bio-físicas de los páramos de Nariño. Pasto, Corporación Autónoma Regional de Nariño - Corponariño, Grupo de investigación en biología de páramos y ecosistemas Andinos, Universidad de Nariño.

Stancik D and Peterson PM (2007) A Revision of *Festuca* (Poaceae: Loliinae) in South American Páramos. *Contributions from the United States National Herbarium*, 56, 1–184.

Stein A, Gerstner K and Kreft H (2014) Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. *Ecology Letters*, 17, 866–880.

Suding KN, Lavorel S, Chapin III FS, Cornelissen JHC, Díaz S, Garnier E, Goldberg D, Hooper DU, Jackson ST and Navas M (2008) Scaling environmental change through the community-level: a trait-based response-and-effect framework for plants. *Global Change Biology*, 14, 1125-1140.

Sultan SE (1995) Phenotypic plasticity and plant adaptation. *Acta Botanica Neerlandica*, 44, 363-383.

Sultan SE and Spencer HG (2002) Metapopulation structure favors plasticity over local adaptation. *The American Naturalist*, 160, 271-283.

Ter Braak CJF (1986) Canonical correspondence analysis: a new eigenvector technique of for multivariate direct gradient analysis. *Ecology*, 67, 1167-1179.

terHorst CP and Munguia P (2008) Measuring ecosystem function: consequences arising from variation in biomass-productivity relationships. *Community Ecology*, 9, 39-44.

The Plant List (2010) Version 1. Published on the Internet; <http://www.theplantlist.org/>

Thomopoulos NT (2017) Statistical distributions: applications and parameter estimates. Cham, Switzerland: Springer.

Tilman D (1993) Community diversity and succession: the roles of competition, dispersal and habitat modification. In E. D. Schulze and H. A. Mooney (Eds.) *Biodiversity and Ecosystem Function*. Berlin, Germany: Springer. 327-344 pp.

Tilman D (1986) Plant strategies and the dynamics and structure of plant communities. *Monographs in population biology* 26. Princeton University Press, Princeton, 360 pp.

Tilman D, Knops J, Wedin D, Reich P, Ritchie M, Siemann E (1997) The influence of functional diversity and composition on ecosystem processes. *Science*, 277, 1300-1302.

Tol GJ and Cleef AM (1992) Above-ground biomass structure of a *Chusquea tessellata* bamboo páramo, Chingaza National Park, Cordillera Oriental, Colombia. *Vegetatio*, 115, 29-39.

Tonneijck FH, Jansen B, Nierop KGJ, Verstraten JM, Sevink J, De Lange L (2010) Towards understanding of carbon stocks and stabilization in volcanic ash soils in natural Andean ecosystems of northern Ecuador. *Eur J Soil Sci* 61, 392-405.

Torres AM, Peña EJ, Zuñiga O and Peña J (2012) Evaluación del impacto de actividades antrópicas en el almacenamiento de carbono en biomasa vegetal en ecosistemas de alta montaña de Colombia. *Boletín Científico Museo de Historia Natural*, 16, 132-142.

Torres V, Hooghiemstra H, Lourens L. and Tzedakis PC (2013) Astronomical tuning of long pollen records reveals the dynamic history of montane biomes and lake levels in the tropical high Andes during the Quaternary. *Quaternary Science Reviews*, 63, 59-72.

Totland O and Nylehn J (1998) Assessment of the effects of environmental change on the performance and density of *Bistorta vivipara*: the use of multivariate analysis and experimental manipulation. *Journal of Ecology*, 86, 989-998.

Totland O (1999) Effects of temperature on performance and phenotypic selection on plant traits in alpine *Ranunculus acris*. *Oecologia*, 120, 242-251.

Tovar C, Arnillas CA, Cuesta F and Buytaert W (2013) Diverging Responses of Tropical Andean Biomes under Future Climate Conditions. *PLoS One*, 8, 1-12.

Tovar C, Duivenvoorden JF, Sánchez-Vega I. and Seijmonsbergen A. C (2012) Recent changes in patch characteristics and plant communities in the jalca grasslands of the Peruvian Andes. *Biotropica*, 44, 321–330.

Tovar C, Seijmonsbergen AC and Duivenvoorden JF (2013) Monitoring land use and land cover change in mountain regions: An example in the Jalca grasslands of the Peruvian Andes. *Landscape and Urban Planning*, 112, 40–49.

Tropicos (2017) Tropicos.org. St. Louis, USA: Missouri Botanical Garden. Retrieved from <http://www.tropicos.org>

Umaña MN, Zhang C, Cao M, Lin L and Swenson NG (2015) Commonness, rarity, and intraspecific variation in traits and performance in tropical tree seedlings. *Ecology Letters*, 18, 1329–1337.

Valladares F, Matesanz S, Guilhaumon F, Araújo MB, Balaguer L, Benito-Garzón (et al.) Zavala MA (2014) The effects of phenotypic plasticity and local adaptation on forecasts of species range shifts under climate change. *Ecology Letters*, 17, 1351–1364.

Van der Hammen T and Cleef AM (1986) Development of the high andean páramo flora and vegetation, pp. 153–201. Vuillemier F. and Monasterio M (eds.). High altitude tropical biogeography. Oxford Univ.Press.

Van der Hammen T (1974) The Pleistocene Changes of Vegetation and Climate in Tropical South America. *Journal of Biogeography*, 1, 3–26.

Van der Hammen T and Hooghiemstra H (2000) Neogene and Quaternary history of vegetation, climate, and plant diversity in Amazonia. *Quaternary Science Reviews*, 19, 725–742.

Van der Hammen T, Werner J and van Dommelen H (1973) Palynological Record of the Upheaval of the Northern Andes: a Study of the Pliocene and Lower Quaternary of the Colombian Eastern Cordillera and the Early Evolution of Its High-Andean Biota. *Review of Paleobotany and Palynology*, 16, 1–122.

Vargas OM (2011) A nomenclator of *Diplostephium* (Asteraceae: Astereae): A List of Species with their Synonyms and Distribution. *Lundellia*, 14, 32–51.

Vargas OM, Ortiz EM and Simpson BB (2017) Conflicting phylogenomic signals reveal a pattern of reticulate evolution in a recent high-Andean diversification (Asteraceae: Astereae: *Diplostephium*). *New Phytologist*, 214: 1736–1750.

Vargas RO (1996) Impacto del fuego y pastoreo sobre el medio ambiente páramo. In: Reyes Z, P (ed.) El páramo: Ecosistema para proteger. Fundación Ecosistema Andinos ECOAN, Bogotá. 63-72 pp.

Vargas O (1997) Un modelo de sucesión-regeneración de los páramos después de quemadas. *Caldasia*, 19, 331–345.

Verweij P (1995) Spatial and temporal modelling of vegetation patterns: burning and grazing in the páramo of Los Nevados National Park, Colombia. PhD thesis University of Amsterdam

Verweij PA, Kok K and Budde PE (2003) Aspectos de la transformación del páramo por el hombre. In: Van der Hammen T and Dos Santos A (eds.) La Cordillera Central Colombiana. Transecto Parque Los Nevados. pp. 429–452. J. Cramer, Berlin-Stuttgart, Germany.

Violle C, Enquist BJ, McGill BJ, Jiang L, Albert CH, Hulshof C, Jung V and Messier J (2012) The return of the variance: Intraspecific variability in community ecology. *Trends in Ecology and Evolution*, 27, 244–252.

Violle C, Navas ML, Vile D, Kazakou E, Fortunel C, Hummel I and Garnier E (2007) Let the concept of trait be functional! *Oikos*, 116, 882–892.

Vuille M, Bradley R, Werner M and Keimig FM (2003) 20th century climate change in the tropical Andes: observations and model results. *Climatic Change*, 59, 75–99.

Walker B, Kinzig A. and Langridge J (1999) Plant attribute diversity, resilience, and ecosystem function: the nature and significance of dominant and minor species. *Ecosystems*, 2, 95–113.

Webb CO and Donoghue MJ (2005) PHYLOMATIC: tree assembly for applied phylogenetics. *Molecular Ecology Notes*, 5, 181–183.

Webb CO, Ackerly DD and Kembel SW (2008) Phylocom: software for the analysis of phylogenetic community structure and trait evolution, 1–2.

Weiherr E, Clarke G. D. P. and Keddy P. A (1998) Community assembly rules, morphological dispersion, and the coexistence of plant species. *Oikos*, 81, 309–322.

Weiherr E, van der Werf A, Thompson K, Roderick M, Garnier E and Eriksson O (1999) Challenging Theophrastus: a common core list of plant traits for functional ecology. *Journal of Vegetation Science*, 10, 609–620.

Wellstein C, Chelli S, Campetella G, Bartha S, Galie M, Spada F and Canullo R (2013) Intraspecific phenotypic variability of plant functional traits in contrasting mountain grasslands habitats. *Biodiversity and Conservation*, 22, 2353–2374

Westoby M (1998) A leaf-height-seed (LHS) plant ecology strategy scheme. *Plant and Soil*, 199, 213–227.

Westoby M, Falster DS, Moles AT, Vesk PA and Wright IJ (2002) Plant ecological strategies: some leading dimensions of variation between species. *Annual Review of Ecology and Systematics*, 33, 125–159.

Wheeler GA and Beck SG (2011) A new combination in *Carex* (Cyperaceae) and the first report of five other *Cariceae* from Bolivia. *Revista de la Sociedad Boliviana de Botánica*, 5, 47–52. White RE (2006) *Principles and practice of soil science*, 4th edn. Blackwell, Malden.

Wilson PJ, Thompson K and Hodgson JG (1999) Specific leaf area and dry leaf matter content as alternative predictors of plant strategies. *New Phytologist*, 143, 155–162.

Xiao X, White E, Hooten M and Durham S (2011) On the use of log-transformation vs. nonlinear regression for analyzing biological power-laws. *Ecology*, 92, 1887–1894.

Zavaleta E, Pasari J, Moore J, Hernández D, Suttle K.B. and Wilmers CC (2009) Ecosystem responses to community disassembly. *Annals of the New York Academy of Sciences*, 1162, 311–333.

Zianis D and Mencuccini M (2004) On simplifying allometric analyses of forest biomass. *Forest Ecology and Management*, 187, 311–332.

Zuur A, Ieno EN, Walker N, Saveliev AA and Smith GM (2009) *Mixed Effects Models and Extensions in Ecology with R*. Springer, New York, US. 574 pp.