



## 1. DATOS BÁSICOS DEL TFG:

**Título:** Análisis de los cambios en la composición de la vegetación de alta montaña (Sierra Nevada; SE España) en parcelas permanentes durante los últimos 21 años (2001-2022)

### Descripción general (resumen y metodología):

Introducción: En la actualidad las zonas alpinas están entre las regiones en las que se prevé un calentamiento global superior a la media mundial. Al mismo tiempo la presión humana está aumentando debido a una creciente presión turística y a cambios de uso del suelo. Dado que las plantas responden al duro entorno alpino con un alto grado de especialización, estos factores pueden ser especialmente perjudiciales para ellas. Para estudiar los cambios a largo plazo se establecieron en 2001, en el marco del proyecto internacional GLORIA distintas parcelas permanente en Sierra Nevada. Desde ese momento se han tomado una serie imágenes (photoplots) de las parcelas, pero no se han analizado hasta el momento, por lo que el análisis de estas imágenes puede ofrecer interesantes resultados sobre los cambios que se están produciendo en estas zonas.

Metodología/Plan de trabajo:

1º Recopilación de imágenes y organización en cronosecuencias.

2º Búsqueda de información bibliográfica y establecimiento de metodología de análisis de imágenes

3º Fotointerpretación de imágenes mediante software específico.

4º Análisis de los datos obtenidos.

5º Elaboración de resultados y redacción de la memoria de TFG

**Tipología:** Trabajos experimentales, de toma de datos de campo o de laboratorio.

### Objetivos planteados:

Analizar los cambios experimentados en la vegetación de alta montaña en los últimos 21 años mediante análisis de imágenes.

### Bibliografía básica:

Abeli T, Vamosi JC, Orsenigo S (2018) The importance of marginal population hotspots of coldadapted

species for research on climate change and conservation. *J Biogeogr* 45:977-985.

<https://doi.org/10.1111/jbi.13196>

Amano T, Smithers RJ, Sparks TH, Sutherland WJ (2010) A 250-year index of first flowering dates and its response to temperature changes. *Proc R Soc Ser B Biol Sci* 277:2451-2457.

<https://doi.org/10.1098/rspb.2010.0291>

Anderson RS, Jiménez-Moreno G, Carrión JS, Pérez-Martínez C (2011) Postglacial history of alpine vegetation, fire, and climate from Laguna de Río Seco, Sierra Nevada, southern Spain. *Quat Sci Rev* 30:1615-1629. <https://doi.org/10.1016/j.quascirev.2011.03.005>

Benito B, Lorite J, Peñas J (2011) Simulating potential effects of climatic warming on altitudinal patterns of key species in Mediterranean-alpine ecosystems. *Clim Change* 108:471-483

Benito BM, Lorite J, Pérez-Pérez R, et al (2014) Forecasting plant range collapse in a mediterranean hotspot: When dispersal uncertainties matter. *Divers Distrib* 20:72-83

Blanca G, Cueto M, Martínez-Lirola MJ, Molero-Mesa J (1998) Threatened vascular flora of sierra nevada (southern spain). *Biol Conserv* 85:269-285. [https://doi.org/10.1016/S0006-3207\(97\)00169-9](https://doi.org/10.1016/S0006-3207(97)00169-9)

Blanca G, López-Onieva MR, Lorite J, et al (2001) Flora amenazada y endémica de Sierra Nevada

Bravo DN, Araújo MB, Lasanta T, Moreno JIL (2008) Climate change in Mediterranean mountains during the 21st century. *Ambio* 37:280–285. [https://doi.org/10.1579/0044-7447\(2008\)37\[280:CCIMMD\]2.0.CO;2](https://doi.org/10.1579/0044-7447(2008)37[280:CCIMMD]2.0.CO;2)

Cañadas EM, Fenu G, Peñas J, et al (2014) Hotspots within hotspots: Endemic plant richness, environmental drivers, and implications for conservation. *Biol Conserv* 170:282–291

Casagrande Bacchiocchi S, Zerbe S, Cavieres LA, Wellstein C (2019) Impact of ski piste management on mountain grassland ecosystems in the Southern Alps. *Sci Total Environ* 665:959–967. <https://doi.org/10.1016/j.scitotenv.2019.02.086>

Dullinger S, Gattringer A, Thuiller W, et al (2012) Extinction debt of high-mountain plants under twenty-first-century climate change. *Nat Clim Chang* 2:619–622. <https://doi.org/10.1038/nclimate1514>

Engler R, Randin CF, Thuiller W, et al (2011) 21st century climate change threatens mountain flora unequally across Europe. *Glob Chang Biol* 17:2330–2341. <https://doi.org/10.1111/j.1365-2486.2010.02393.x>

Engler R, Randin CF, Vittoz P, et al (2009) Predicting future distributions of mountain plants under climate change: does dispersal capacity matter? *Ecography (Cop)* 32:34–45. <https://doi.org/10.1111/j.1600-0587.2009.05789.x>

Essl F, Staudinger M, Stöhr O, et al (2009) Distribution patterns, range size and niche breadth of Austrian endemic plants. *Biol Conserv* 142:2547–2558. <https://doi.org/10.1016/j.biocon.2009.05.027>

Fernández-Calzado MR, Molero J (2013) Changes in the summit flora of a Mediterranean mountain (Sierra Nevada, Spain) as a possible effect of climate change. *LAZAROA* 34:65–75. [https://doi.org/10.5209/rev\\_LAZA.2013.v34.n1.41523](https://doi.org/10.5209/rev_LAZA.2013.v34.n1.41523)

Fernández Calzado MR, Molero Mesa J, Fernández-Calzado MR, Molero J (2011) The cartography of vegetation in the cryoromediterranean belt of Sierra Nevada: a tool for biodiversity conservation. *Lazaroa* 32:101–115. <https://doi.org/10.5209/rev-LAZA.2011.V32.37255>

Fernández Calzado MR, Molero Mesa J, Merzouki A, Casares Porcel M (2012) Vascular plant diversity and climate change in the upper zone of Sierra Nevada, Spain. *Plant Biosyst* 146:1044–1053. <https://doi.org/10.1080/11263504.2012.710273>

Franks SJ, Hoffmann AA (2012a) Genetics of Climate Change Adaptation. *Annu Rev Genet* 46:185–208. <https://doi.org/10.1146/annurev-genet-110711-155511>

García D, Zamora R, Hódar JA, Gómez JM (1999) Age structure of *Juniperus communis* L. in the Iberian peninsula: Conservation of remnant populations in Mediterranean mountains. *Biol Conserv* 87:215–220. [https://doi.org/10.1016/S0006-3207\(98\)00059-7](https://doi.org/10.1016/S0006-3207(98)00059-7)

Gómez-Ortiz A, Oliva M, Salvà-Catarineu M, Salvador-Franch F (2013) The environmental protection of landscapes in the high semiarid Mediterranean mountain of Sierra Nevada National Park (Spain): Historical evolution and future perspectives. *Appl Geogr* 42:227–239. <https://doi.org/10.1016/j.apgeog.2013.02.006>

Gómez JM, González-Megías A, Lorite J, et al (2015) The silent extinction: climate change and the potential hybridization-mediated extinction of endemic high-mountain plants. *Biodivers Conserv* 24:1843–1857. <https://doi.org/10.1007/s10531-015-0909-5>

Gottfried M, Pauli H, Futschik A, et al (2012) Continent-wide response of mountain vegetation to climate change. *Nat Clim Chang* 2:111–115. <https://doi.org/10.1038/nclimate1329>

Grabherr G, Gottfried M, Pauli H (1994) Climate effects on mountain plants. *Nature* 369:448–448. <https://doi.org/10.1038/369448a0>

Hughes L (2000) Biological consequences of global warming: Is the signal already apparent? *Trends Ecol. Evol.* 15

Hülber K, Winkler M, Grabherr G (2010) Intraseasonal climate and habitat-specific variability controls the flowering phenology of high alpine plant species. *Funct Ecol* 24:245–252. <https://doi.org/10.1111/j.1365-2435.2009.01645.x>

Jansson R (2003) Global patterns in endemism explained by past climatic change. *Proc R Soc London Ser B Biol Sci* 270:583–590. <https://doi.org/10.1098/rspb.2002.2283>

Jump AS, Mátyás C, Peñuelas J (2009) The altitude-for-latitude disparity in the range retractions of

woody species. *Trends Ecol Evol* 24:694–701. <https://doi.org/10.1016/j.tree.2009.06.007>

Kelly AE, Goulden ML (2008) Rapid shifts in plant distribution with recent climate change. *Proc Natl Acad Sci* 105:11823–11826. <https://doi.org/10.1073/pnas.0802891105>

Körner C (2012) *Alpine Treelines*. Springer Basel, Basel

Körner C (2021) *Alpine Plant Life*. Springer International Publishing, Cham

Körner C (2003) *Alpine Plant Life*, 2a edn. Springer Berlin Heidelberg, Berlin, Heidelberg

La Sorte FA, Jetz W (2010) Projected range contractions of montane biodiversity under global warming. *Proc R Soc B Biol Sci* 277:3401–3410. <https://doi.org/10.1098/rspb.2010.0612>

Lamprecht A, Pauli H, Fernández-Calzado MR, et al (2021) Changes in plant diversity in a waterlimited and isolated high-mountain range (Sierra Nevada, Spain). *Alp Bot*. <https://doi.org/10.1007/s00035-021-00246-x>

Lamprecht A, Rutzinger M, Pauli H, et al (2019a) Disentangling anthropogenic drivers of climate change impacts on alpine plant species : Alps vs . Mediterranean mountains

Lenoir J, Gégout JC, Marquet P a, et al (2008) A significant upward shift in plant species optimum elevation during the 20th century. *Science* 320:1768–1771. <https://doi.org/10.1126/science.1156831>

Lorite J (2016) An updated checklist of the vascular flora of Sierra Nevada (SE Spain). *Phytotaxa* 261:1–57. <https://doi.org/10.11646/phytotaxa.261.1.1>

Lorite J, Valle F, Salazar C (2003) Síntesis de la vegetación edafohigrófila del Parque Natural y Nacional de Sierra Nevada. *Monogr Flora y Veg Béticas* 13:47–110

McNeill J (1992) *The Mountains of the Mediterranean World*. Cambridge University Press., Cambridge

Médail F, Diadema K (2009) Glacial refugia influence plant diversity patterns in the Mediterranean Basin. *J Biogeogr* 36:1333–1345. <https://doi.org/10.1111/j.1365-2699.2008.02051.x>

Medail F, Quezel P, Médail F, Quézel P (1999) Biodiversity Hotspots in the Mediterranean Basin: Setting Global Conservation Priorities. *Conserv Biol* 13:1510–1513

Myers N, Mittermeier RA, Mittermeier CG, et al (2000) Biodiversity hotspots for conservation priorities. *Nature* 403:853

Nagy L (2006) European High Mountain (Alpine) Vegetation and its Suitability for Indicating Climate Change Impacts. *Biol Environ Proc R Irish Acad* 106:335–341. <https://doi.org/10.3318/BIOE.2006.106.3.335>

Nagy L, Grabherr G (2009) *The Biology of Alpine Habitats*. Oxford University Press, Oxford

Nagy L, Grabherr G, Körner C, Thompson DBA (2003) *Alpine Biodiversity in Europe*. Springer Berlin Heidelberg, Berlin, Heidelberg

Nogués-Bravo D, Araújo MB, Lasanta T, et al (2008) Climate change in Mediterranean mountains during the 21st century. *Ambio* 37:280–285. [https://doi.org/10.1579/0044-7447\(2008\)37\[280:CCIMMD\]2.0.CO;2](https://doi.org/10.1579/0044-7447(2008)37[280:CCIMMD]2.0.CO;2)

Ohlemüller R, Anderson BJ, Araújo MB, et al (2008) The coincidence of climatic and species rarity: high risk to small-range species from climate change. *Biol Lett* 4:568–572. <https://doi.org/10.1098/rsbl.2008.0097>

Parmesan C (2007) Influences of species, latitudes and methodologies on estimates of phenological response to global warming. *Glob Chang Biol* 13:1860–1872. <https://doi.org/10.1111/j.1365-2486.2007.01404.x>

Parmesan C, Yohe G (2003) A globally coherent fingerprint of climate change. *Nature* 421:37–42

Pauli H, Gottfried M, Dullinger S, et al (2012) Recent Plant Diversity Changes on Europe's Mountain Summits. *Science* (80- ) 336:353–355. <https://doi.org/10.1126/science.1219033>

Pauli H, Gottfried M, Lamprecht A, et al (2015) *The GLORIA field manual – standard Multi-Summit approach, supplementary methods and extra approaches*, 5th edn. GLORIA-Coordination, Austrian Academy of Sciences & University of Natural Resources and Life Sciences, Vienna

Peñas J, Lorite J (2019) *Biología de la conservación de plantas en Sierra Nevada. Principios y retos para su preservación*. Editorial Universidad de Granada, Granada

Peñuelas J, Filella I (2001) Phenology: Responses to a warming world. *Science* (80-. ). 294:793–795

Pepin N, Bradley RS, Diaz HF, et al (2015) Elevation-dependent warming in mountain regions of the world. *Nat Clim Chang* 5:424–430. <https://doi.org/10.1038/nclimate2563>

Piper FI, Viñeola B, Linares JC, et al (2016) Mediterranean and temperate treelines are controlled by different environmental drivers. *J Ecol* 104:691–702. <https://doi.org/10.1111/1365-2745.12555>

Rixen C, Wipf S (2017) Non-equilibrium in Alpine Plant Assemblages: Shifts in Europe's Summit Floras. In: Catalan J, Ninot J, Aniz M (eds) *High Mountain Conservation in a Changing World*. Springer, Cham., pp 285–303

Roux-Fouillet P, Wipf S, Rixen C (2011) Long-term impacts of ski piste management on alpine vegetation and soils. *J Appl Ecol* 48:906–915. <https://doi.org/10.1111/j.1365-2664.2011.01964.x>

Roux PC le, Virtanen R, Heikkinen RK, Luoto M (2012a) Biotic interactions affect the elevational ranges of high-latitude plant species. *Ecography (Cop)* 35:1048–1056. <https://doi.org/10.1111/j.1600-0587.2012.07534.x>

Ruiz FA, Vázquez M, Camuñez JA, et al (2020) Characterization and challenges of livestock farming in Mediterranean protected mountain areas (Sierra Nevada, Spain). *Spanish J Agric Res* 18:e0601. <https://doi.org/10.5424/sjar/2020181-14288>

Rumpf SB, Hülber K, Klöner G, et al (2018) Range dynamics of mountain plants decrease with elevation. *Proc Natl Acad Sci* 115:1848–1853. <https://doi.org/10.1073/pnas.1713936115>

Sanders NJ, Rahbek C (2012) The patterns and causes of elevational diversity gradients. *Ecography (Cop)* 35:1–3. <https://doi.org/10.1111/j.1600-0587.2011.07338.x>

Smith J, Sconiers W, Spasojevic M, et al (2012) Phenological changes in alpine plants in response to increased snowpack, temperature, and nitrogen. *Arctic, Antarct Alp Res* 44:135–142. <https://doi.org/10.1657/1938-4246-44.1.135>

Steinbauer K, Lamprecht A, Semenchuk P, et al (2020) Dieback and expansions: species-specific responses during 20 years of amplified warming in the high Alps. *Alp Bot* 130:1–11. <https://doi.org/10.1007/s00035-019-00230-6>

Steinbauer MJ, Grytnes J-A, Jurasinski G, et al (2018) Accelerated increase in plant species richness on mountain summits is linked to warming. *Nature* 556:231–234. <https://doi.org/10.1038/s41586-018-0005-6>

Steinbauer MJ, Otto R, Naranjo-Cigala A, et al (2012) Increase of island endemism with altitude - speciation processes on oceanic islands. *Ecography (Cop)* 35:23–32. <https://doi.org/10.1111/j.1600-0587.2011.07064.x>

Teubner IE, Haimberger L, Hantel M (2015) Estimating Snow Cover Duration from Ground Temperature. *J Appl Meteorol Climatol* 54:959–965. <https://doi.org/10.1175/JAMC-D-15-0006.1>

Theurillat J, Guisan A (2001) Potential Impact of Climate Change on Vegetation in the European Alps : A Review. *Clim Chang* 77–109. <https://doi.org/10.1023/a:1010632015572>

Thompson JD (2005) *Plant Evolution in the Mediterranean*. Oxford University Press

Thuiller W, Lavorel S, Araújo MB, et al (2005) Climate change threats to plant diversity in Europe. *Proc Natl Acad Sci U S A* 102:8245–8250. <https://doi.org/10.1073/pnas.0409902102>

Vegas-Vilarrúbia T, Nogué S, Rull V (2012) Global warming, habitat shifts and potential refugia for biodiversity conservation in the neotropical Guayana Highlands. *Biol Conserv* 152:159–168. <https://doi.org/10.1016/j.biocon.2012.03.036>

Vitt P, Havens K, Kramer AT, et al (2010) Assisted migration of plants: Changes in latitudes, changes in attitudes. *Biol Conserv* 143:18–27. <https://doi.org/10.1016/j.biocon.2009.08.015>

Vogiatzakis IN (2012) *Mediterranean Mountain Environments*. John Wiley & Sons, Ltd, Chichester, UK

Walther G-R (2003) Plants in a warmer world. *Perspect Plant Ecol Evol Syst* 6:169–185. <https://doi.org/10.1078/1433-8319-00076>

Walther G-R, Beißner S, Burga C a. (2005) Trends in the upward shift of alpine plants. *J Veg Sci* 16:541–548. <https://doi.org/10.1111/j.1654-1103.2005.tb02394.x>

### **Recomendaciones y orientaciones para el estudiante:**

**Plazas:** 1

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