frontiers | Frontiers in Forests and Global Change

TYPE Opinion
PUBLISHED 05 February 2025
DOI 10.3389/ffgc.2025.1377026

OPEN ACCESS

EDITED BY
Jürgen Homeier,
University of Applied Sciences and Arts (HAWK), Germany

REVIEWED BY
Xiangjin Shen,
Chinese Academy of Sciences (CAS), China
Sumit Chakravarty,
Uttar Banga Krishi Viswavidyalaya, India

*CORRESPONDENCE
José Omar Bava
✉ jbava@ciefap.org.ar
Marina Caselli
✉ mcaselli@ciefap.org.ar

RECEIVED 26 January 2024
ACCEPTED 20 January 2025
PUBLISHED 05 February 2025

CITATION
Bava JO and Caselli M (2025) Forestry, from theory to practice: Central European ideas in native Patagonian forests in a context of climate change.
Front. For. Glob. Change 8:1377026.
doi: 10.3389/ffgc.2025.1377026

Forestry, from theory to practice: Central European ideas in native Patagonian forests in a context of climate change

José Omar Bava[1,2]* and Marina Caselli[1,3]*

[1]Andean Patagonian Forest Research and Extension Center (CIEFAP), Esquel, Argentina, [2]Department of Forestry, Faculty of Engineering, National University of Patagonia San Juan Bosco, Esquel, Argentina, [3]National Council for Scientific and Technical Research (CONICET), Esquel, Argentina

KEYWORDS

sustainable forest management, forest production, biodiversity, forest services, Argentinian forestry

1 Introduction

In recent decades restoration, conservation, and sustainable forest management have been fundamental in mitigating global climate change (Zhang et al., 2021; Kauppi et al., 2022; Gregor et al., 2022). Through sustainable forest management (SFM), mitigation can be extended by conserving carbon in forest products (Nabuurs et al., 2018; Verkerk et al., 2020; Tognetti et al., 2022; Loguercio et al., 2024). However, climate change affects the health of the forest and jeopardizes the capacity of forest managers to achieve their objectives and meet forest-related needs of society (FAO, 2017), affecting SFM in many aspects, such as tree growth, tree mortality due to drought and heat, pathogen outbreak, and inducing changes in disturbance regimes, particularly fire (Keenan, 2015; Cailleret et al., 2017; Choat et al., 2018; Upadhyay and Tripathi, 2019; Kitzberger et al., 2022; Reiter et al., 2024).

The new context has promoted an adaptation of traditional forestry toward a new forest management paradigm. While, in a general framework, traditional forestry has been based on simplifying forest structures and minimizing or avoiding disturbances, the new paradigm highlights the importance of maintaining and increasing the variability of forest structures as a tool for ecosystem adaptation (Puettmann et al., 2009; Donoso et al., 2013; O'Hara and Ramage, 2013; Lafond et al., 2014; Isbell et al., 2015; Bowditch et al., 2020). This new approach requires monitoring forest functions and anticipating the effects of disturbances to carry out resilient actions that avoid negative consequences on forest services and productivity (Santopuoli et al., 2021; Tognetti et al., 2022). This can be done through nature-based solutions and close-to-nature silviculture (Brang et al., 2014), which are important components of climate-smart forest management, to increase timber production, adaptation, and mitigation sustainably.

The forests of Argentinian Northpatagonia provide goods and services and contribute to the comprehensive development of the region. Their current distribution has been modeled mainly by anthropic fire at the beginning of the colonization of the territory (Veblen et al., 2003; Defossé et al., 2020), and was conditioned by the revegetation capacity of the species and the existence of fire refuges (Veblen and Lorenz, 1987; Kitzberger, 1994). Added to the risk of new catastrophic fires, north Patagonian forests under forest management are scarce, and some of them are subjected to extractive activities without planning, compromising sustainability and the forest's ability to adapt to changes (Grosfeld et al., 2019).

The forest disturbances, whether natural or anthropic, interact with climate change, impacting ecosystems and the well-being of the associated populations (Suarez and Kitzberger, 2010; Amoroso et al., 2015; Rodríguez-Catón et al., 2016). Climate change strongly affects Patagonian forests, because biodiversity in the mountains, which includes exclusive species and a richness conditioned by small-scale environmental heterogeneity, is particularly vulnerable to rapid change (Tognetti et al., 2022; Adler et al., 2023). Since the late 1970s, the combination of fluctuations in ocean-atmosphere climate variability patterns has resulted in warmer and drier conditions across southern South America (Garreaud et al., 2009; Jacques-Coper and Garreaud, 2015). Further, the climate change scenarios for this region predict a reduction in rainfall and an increase in mean summer temperature (DGF CONAMA, 2006). For this reason, in promoting SFM, it is crucial to maintain and/or improve forest resilience and resistance (Lloret et al., 2011; Tognetti et al., 2022).

Northpatagonian forests also present a particular situation of demand for forestry production. Wood production from local native forests has historically been declining, and most of the wood comes from forests established more than 2,500 km away. From the point of view of the carbon balance, this demand could be better supplied with wood from the sustainable management of the local native forests, whose productive potential does not exceed 40% of the total forest area of the region. On the other hand, the lack of use pressure on the local wood resources can be considered an advantage for achieving SFM, taking into account the authorities' low capacity to supervise forestry activity.

The objective of this paper is to propose for discussion the main features of a concept that critically considers the local conditions, both natural and socioeconomic, to promote a cautious use of the Northpatagonian forests in a scenario of uncertainty.

2 Theoretical and practical bases for management

The principles of sustainable management of native forests have been applied in Central Europe for more than 200 years (Burschel and Huss, 1997). Argentine and Chilean foresters, trained based on the Central European forestry school, were invited to adapt the Patagonian forests to silvicultural systems that were developed in Central European temperate forests (Martínez-Pastur et al., 2003), with similar dynamic processes, but with another framework. In north Patagonia most of the forests are in a natural state, therefore, the direct application of the same management practices perfectioned in Central Europe is not easy.

The paradigm for the adaptation to Central European management systems is that the most cautious practice is to understand local natural dynamics processes and try to imitate them. However, the application of this idea should not only consider the ecological characteristics but also the socio-economic system. There is a marked difference in the degree of anthropization between Central European and Northpatagonian forests. In Patagonia, we work in primary or secondary post-fire forests. So, in general, it is not possible to identify stands similar to those present in managed forests in Central Europe, as changes in the structure tend to occur along gradients. The socio-economic context for forest management in Patagonia is also different from Central Europe, especially in the institutional framework, the profitability of the system, the level of demand and technology, the idiosyncrasies of the actors, and the technical expertise. In North Patagonia, most forests belong to private farmers who, as a result of a new forestry law, since 2007, have to submit a management plan if it is intended to log their forests. They are generally livestock producers who have shown little or no interest in incorporating forestry into their productive system (Grosfeld et al., 2019). However, they may occasionally show interest in carrying out small forest interventions for one or a few years. In this case, the role of forest managers should not be to propose SFM in perpetuity at the property level, but rather, on the contrary, should focus on providing sustainability conditions for each of the isolated interventions, considering the forest potential at the landscape level.

Furthermore, the challenge of climate change is inducing changes in the way silviculture is applied and in the objectives of forest management in Central Europe, mainly focused on a "naturalization" of forest strategy (Gregor et al., 2022). However, worldwide climate change restricts the paradigm of imitating the natural dynamic of the forest through management. We can no longer know for sure what this "natural dynamic" is, since climate change modifies the type, frequency, and intensity of disturbances and, therefore, the dynamic processes (O'Hara, 2016). In this context, we, like Central European foresters, are forced to provide guidelines for managing and restoring forests in a framework of very high uncertainty (Lawrence, 2016; Tognetti et al., 2022), although starting from very different reference ecosystems and socio-economic conditions.

3 Discussion

The scarcity of demand for wood production in Northpatagonian forests can be seen as an opportunity, in the same way as the relatively close-to-nature state of most of the forests. Thus, it should be easier to move toward a sustainable management process if the wood demand is low and the forest structure is heterogeneous. Furthermore, certain processes and services are better preserved than in Central European forests, for example, the role of woody debris in biodiversity (Loguercio et al., 2019, 2024). Our efforts then, must be aimed at preserving these attributes while carrying out SFM for wood production.

A reasonable recommendation for Patagonian native forests would be an adaptative management forest approach that minimizes the changes caused to the forest. This approach has been applied in other parts of Europe, i.e. through Continuous Cover Forestry (Mason et al., 2022) and climate-smart forest management (Nabuurs et al., 2018). The selection of trees to be harvested and favored must be adjusted to micro-scale structural variations, without attempting to homogenize the surface. This would give the forest greater resistance and resilience to disturbances (Tognetti et al., 2022). At the same time, part of the canopy should remain occupied by large ancient trees to maintain biodiversity (Ceddia et al., 2014) and improve microclimatic conditions by reducing desiccating winds. This entails an artisan selection and a very careful falling. This is feasible in low-scale productions of small farmers. This scale could be also well managed and supervised by the local forestry services. Besides, the duration of easily flammable seral stages of shrubland communities should be shortened with the rapid progression toward high forests (of greater carbon capture and stock) (Gowda et al., 2023; Loguercio et al., 2024), although preserving resprouting species as insurance for rapid recovery in case of burning. Managing forest disturbances, favoring resilient trees, implementing forest reserves, combining carbon storage, sequestration, and substitution, using forest bioenergy and wood for long-lived uses, and preventing land degradation by forest goods and services revalorization, must be our guiding light.

As the demand for logging interventions comes from farmers who do not have long-term forestry plans, sustainability has to be considered at a forestry basin scale, using this level of planning to calculate the annual allowable cut rather than the property level. This requires broadening the knowledge about the structure, growth, dynamics, and possible responses to disturbances of our native forests, but mainly focusing on practice (Lawrence, 2016), carrying out silvicultural interventions based on this knowledge. That is, managing forests without having in mind a complete picture of the future or target forest. Therefore, it is necessary to have permanent monitoring systems that allow periodic analysis of the effects of interventions and their interaction with the climate, to make scientifically-based management decisions (Tognetti et al., 2022). This information could be obtained from a combination of remote sensing technologies, and through temporal and permanent forest plots. In this sense, some initiatives are starting to get underway, e.g., the recently created Forest-Climate Network of Argentina and the KLIMNEM project (Walentowski et al., 2020). However, there are only a few experiences of implementation of forestry schemes in experimental plots in Northpatagonia, much of them being successful but lacking continuity, which prevents detailed analysis, and makes scaling and planning at the landscape level difficult.

On the other hand, some Northpatagonian forests have been gradually degraded due to deficiencies in the management of herbivory, unplanned forest harvesting, and large-scale fires, whose frequency exceeds that defined as natural. The environmental conditions for the recovery of these forests differ from the conditions in which they originated, so the success of the natural recovery processes is largely unknown. Since climate change continues and accelerates, probably in the most extreme conditions it will be necessary to perform active restoration, for which the question of the inclusion of exotic species and assisted migration remains open.

So, we work in a different framework from Central Europe, and there are not enough experiences of successful adaptations in long-term forest management in North Patagonia, but as foresters, it is our task to continue learning from the challenges and take advantage of the opportunities. Climate change is here to stay and does not allow us to predict expected responses to our actions. The literature can guide us, but we must find the procedures that lead us to sustainable management (Burschel and Huss, 1997). The challenge of applying forestry adapted to Patagonian forest ecosystems opens up a range of possibilities and questions in the search for sustainability. Our efforts to deepen our knowledge of the functioning of these natural ecosystems and increase experimentation in managed forests will be the tools to make the right choices. Our goal will be to contribute to the maintenance and increase of the forest provision of goods and services, the use of wood for carbon storage, the revaluation of forests by landholders, and the restoration and conservation of forest lands for the good of all humanity.

Author contributions

JB: Conceptualization, Writing – original draft, Writing – review & editing. MC: Conceptualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study was imbedded in the international and interdisciplinary research project “Sustainable forest management of temperate deciduous forests—Northern hemisphere beech and southern hemisphere beech forests” (KLIMNEM), a cooperation between the universities of Göttingen (Germany), Free University of Bozen-Bolzano (Italy), and the Andean Patagonian Forest Research and Extension Centre (CIEFAP, Argentina). The project was supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE, grant no. 28I-042-01).

Acknowledgments

We wish to acknowledge Melisa Rago for her help with English revision and Helge Walentowski for his support.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher’s note

References

Adler, C., Wester, P., Bhatt, I., Huggel, C., Insarov, G., Morecroft, M., et al. (2023). "Cross-chapter paper 5: mountains," in *Climate Change 2022 - Impacts, Adaptation and Vulnerability* (Cambridge; New York, NY: Cambridge University Press), 2273–2318. doi: 10.1017/9781009325844.022

Amoroso, M. M., Daniels, L. D., Villalba, R., and Cherubini, P. (2015). Does drought incite tree decline and death in Austrocedrus chilensis forests? *J. Vegetat. Sci.* 26, 1171–1183. doi: 10.1111/jvs.12320

Bowditch, E., Santopuoli, G., Binder, F., del Río, M., La Porta, N., Kluvankova, T., et al. (2020). What is climate-smart forestry? A definition from a multinational collaborative process focused on mountain regions of Europe. *Ecosyst. Serv.* 43:101113. doi: 10.1016/j.ecoser.2020.101113

Brang, P., Spathelf, P., Larsen, J. B., Bauhus, J., Bončína, A., Chauvin, C., et al. (2014). Suitability of close-to-nature silviculture for adapting temperate European forests to climate change. *Forestry* 87, 492–503. doi: 10.1093/FORESTRY/CPU018

Burschel, P., and Huss, J. (1997). *Grundriss des Waldbaus: Ein Leitfaden für Studium und Praxis*. Singhofen: P. Parey.

Cailleret, M., Jansen, S., Robert, E. M. R., Desoto, L., Aakala, T., Antos, J. A., et al. (2017). A synthesis of radial growth patterns preceding tree mortality. *Glob. Chang. Biol.* 23, 1675–1690. doi: 10.1111/gcb.13535

Ceddia, M. G., Bardsley, N. O., Gomez-Y-Paloma, S., and Sedlacek, S. (2014). Governance, agricultural intensification, and land sparing in tropical South America. *Proc. Natl. Acad. Sci. USA.* 111, 7242–7247. doi: 10.1073/pnas.1317967111

Choat, B., Brodribb, T. J., Brodersen, C. R., Duursma, R. A., López, R., and Medlyn, B. E. (2018). Triggers of tree mortality under drought. *Nature* 558, 531–539. doi: 10.1038/s41586-018-0240-x

Defossé, G. E., Godoy, M. M., and Bertolin, M. L. (2020). Carbon balance and fire emissions in Andean cypress (Austrocedrus chilensis) forests of Patagonia, Argentina. *Int. J. Wildland Fire* 29, 661–674. doi: 10.1071/WF19183

DGF CONAMA (2006). *Estudio de la Variabilidad climática en Chile para el siglo XXI*. Santiago de Chile: Universidad de Chile.

Donoso, P. J., Soto, D. P., Coopman, R. E., and Rodríguez-Bertos, S. (2013). Early performance of planted Nothofagus dombeyi and Nothofagus alpina in response to light availability and gap size in a high-graded forest in the south-central Andes of Chile. *Bosque* 34, 23–32. doi: 10.4067/S0717-92002013000100004

FAO (2017). *FAO Strategy on Climate* Change. Rome: FAO.

Garreaud, R. D., Vuille, M., Compagnucci, R., and Marengo, J. (2009). Present-day South American climate. *Paleogeog. Palaeoclimatol. Palaeoecol.* 281, 180–195. doi: 10.1016/j.palaeo.2007.10.032

Gowda, J. H., Kitzberger, T., and Gonzalez Musso, R. (2023). Modelos de cambio en cobertura forestal de la cuenca del río Manso inferior ¿Una herramienta para definir estrategias de manejo? *Bosque* 44, 273–284. doi: 10.4067/s0717-92002023000100273

Gregor, K., Knoke, T., Krause, A., Reyer, C. P. O., Lindeskog, M., Papastefanou, P., et al. (2022). Trade-offs for climate-smart forestry in Europe under uncertain future climate. *Earth's Future* 10:e2022EF002796. doi: 10.1029/2022EF002796

Grosfeld, J., Chauchard, L., and Gowda, J. H. (2019). Debates: ¿Podemos manejar sustentablemente el bosque nativo de Patagonia Norte? *Ecología Austral* 29, 156–163. doi: 10.25260/EA.19.29.1.0.775

Isbell, F., Craven, D., Connolly, J., Loreau, M., Schmid, B., Beierkuhnlein, C., et al. (2015). Biodiversity increases the resistance of ecosystem productivity to climate extremes. *Nature* 526, 574–577. doi: 10.1038/nature15374

Jacques-Coper, M., and Garreaud, R. D. (2015). Characterization of the 1970s climate shift in South America. *Int. J. Climatol.* 35, 2164–2179. doi: 10.1002/joc.4120

Kauppi, P. E., Stål, G., Arnesson-Ceder, L., Hallberg Sramek, I., Fredrik Hoen, H., Svensson, A., et al. (2022). Managing existing forests can mitigate climate change. *For. Ecol. Manage.* 513:120186. doi: 10.1016/j.foreco.2022.120186

Keenan, R. J. (2015). Climate change impacts and adaptation in forest management: a review. *Ann. For. Sci.* 72, 145–167. doi: 10.1007/s13595-014-0446-5

Kitzberger, T. (1994). *Fire Regime Variation Along a Northern Patagonian Forest-Steppe Gradient: Stand and Landscape Response* (Doctoral dissertation) University of Colorado, Boulder, CO, United States. Available at: https://scholar.google.com/scholar?q=Kitzberger%2C+T.+1994.+Fire+regime+variation+along+a+northern+Patagonian+forest%E2%80%93steppe+gradient%3A+stand+and+landscape+response.+Ph.D.+dissertation%2C+Department+of+Geography%2C+University+of+Colorado%2C+Boulder%2C+Co.#d=gs_cit&t=1705343958116&u=%2Fscholar%3Fq%3Dinfo%3AyOb_rfFT5YcJ%3Ascholar.google.com%2F%26output%3Dcite%26scirp%3D0%26hl%3Des (accessed January 27, 2025).

Kitzberger, T., Tiribelli, F., Barberá, I., Gowda, J. H., Morales, J. M., Zalazar, L., et al. (2022). Projections of fire probability and ecosystem vulnerability under 21st century climate across a trans-Andean productivity gradient in Patagonia. *Sci. Total Environm.* 839:156303. doi: 10.1016/j.scitotenv.2022.156303

Lafond, V., Lagarrigues, G., Cordonnier, T., and Courbaud, B. (2014). Uneven-aged management options to promote forest resilience for climate change adaptation: effects of group selection and harvesting intensity. *Ann. For. Sci.* 71, 173–186. doi: 10.1007/s13595-013-0291-y

Lawrence, J. (2016). Implications of climate change for New Zealand's natural hazards risk management. *Policy Quart.* 12:3. doi: 10.26686/pq.v12i3.4605

Lloret, F., Keeling, E. G., and Sala, A. (2011). Components of tree resilience: effects of successive low-growth episodes in old ponderosa pine forests. *Oikos* 120, 1909–1920. doi: 10.1111/j.1600-0706.2011.19372.x

Loguercio, G., Bertoldi, G., Gianolini, S., Tolosa, J., Villena, P., Lartigau, B., et al. (2019). *Estudio piloto para el muestreo de reservorios de carbono en la madera muerta y en el suelo de la región BAP*. Esquel: CIEFAP.

Loguercio, G. A., Simon, A., Neri Winter, A., Ivancich, H., Reiter, E. J., Caselli, M., et al. (2024). Carbon density and sequestration in the temperate forests of northern Patagonia, Argentina. *Front. For. Glob. Change* 7:1373187. doi: 10.3389/ffgc.2024.1373187

Martínez-Pastur, G., Vukasovic, R. F., Lencinas, M. V., Cellini, J. M., and Wäbo, E. (2003). "El Manejo Silvícola de los Bosques de Patagonia: Utopía o Realidad?," in *XII World Forestry Congress, Quebec, Canada*. Available at: https://www.fao.org/4/xii/0007-b4.htm (accessed January 27, 2025).

Mason, W. L., Diaci, J., Carvalho, J., and Valkonen, S. (2022). Continuous cover forestry in Europe: usage and the knowledge gaps and challenges to wider adoption. *Forestry* 95, 1–12. doi: 10.1093/forestry/cpab038

Nabuurs, G. J., Verkerk, P. J., Schelhaas, M. J., González Olabarria, J. R., Trasobares, A., and Cienciala, E. (2018). "Climate-smart forestry: mitigation impacts in three European regions," in *Climate-Smart Forestry: Mitigation Impacts in Three European Regions* (European Forest Institute).

O'Hara, K. L., and Ramage, B. S. (2013). Silviculture in an uncertain world: Utilizing multi-aged management systems to integrate disturbance. *Forestry* 86, 401–410. doi: 10.1093/forestry/cpt012

O'Hara, K. L. (2016). What is close-to-nature silviculture in a changing world? *Forestry* 89, 1–6. doi: 10.1093/forestry/cpv043

Puettmann, K., Coates, K. D., and Messier, C. C. (2009). *A Critique of Silviculture: Managing for Complexity*. Washington, DC: Island Press.

Reiter, E. J., Weigel, R., Walentowski, H., Loguercio, G. A., Fierke, J., Neri Winter, A., et al. (2024). Climate vulnerability of Nothofagus pumilio, Nothofagus dombeyi and Austrocedrus chilensis in northern Patagonia's temperate forests. *For. Ecol. Manage.* 572:122261. doi: 10.1016/j.foreco.2024.122261

Rodríguez-Catón, M., Villalba, R., Morales, M., and Srur, A. (2016). Influence of droughts on Nothofagus pumilio forest decline across northern Patagonia, Argentina. *Ecosphere* 7, 1–17. doi: 10.1002/ecs2.1390

Santopuoli, G., Temperli, C., Alberdi, I., Barbeito, I., Bosela, M., Bottero, a., et al. (2021). Pan-European sustainable forest management indicators for assessing Climate-Smart Forestry in Europe. *Can. J. Forest Res.* 51, 1741–1750. doi: 10.1139/cjfr-2020-0166

Suarez, M. L., and Kitzberger, T. (2010). Differential effects of climate variability on forest dynamics along a precipitation gradient in northern Patagonia. *J. Ecol.* 98, 1023–1034. doi: 10.1111/j.1365-2745.2010.01698.x

Tognetti, R., Smith, M., and Panzacchi, P. (2022). *Climate-Smart Forestry in Mountain Regions*, eds. R. Tognetti, M. Smith, and P. Panzacchi (Cham: Springer International Publishing).

Upadhyay, K. K., and Tripathi, S. K. (2019). Sustainable forest management under climate change: A dendrochronological approach. *Environ. Ecol.* 37, 998–1006. Available at: https://www.researchgate.net/profile/Keshav-Upadhyay/publication/350724375_Sustainable_Forest_Management_under_Climate_Change_A_Dendrochronological_Approach/links/6082aff1881fa114b4201669/Sustainable-Forest-Management-under-Climate-Change-A-Dendrochronological-Approach.pdf

Veblen, T., and Lorenz, D. (1987). Post-fire stand development of Austrocedrus - Nothofagus forest in Patagonia. *Vegetatio* 73, 113–126. doi: 10.1007/BF00044825

Veblen, T. T., Kitzberger, T., Raffaele, E., and Lorenz, D. C. (2003). Fire history and vegetation changes in Northern Patagonia, Argentina. *Fire Clim. Change Temp. Ecosyst. West. Am.* 9, 265–295. doi: 10.1007/0-387-21710-X_9

Verkerk, P. J., Costanza, R., Hetemäki, L., Kubiszewski, I., Leskinen, P., Nabuurs, G. J., et al. (2020). Climate-smart forestry: the missing link. *Forest Policy Econ.* 115:102164. doi: 10.1016/j.forpol.2020.102164

Walentowski, H., Hohnwald, S., Thren, M., Kappas, M., Leuschner, C., Lencinas, J. D., et al. (2020). Exemplary knowledge transfer between germany and patagonia as contribution to the regional achievement of the UN sustainable development goals 2030. *Biomed. J. Scient. Tech. Res.* 25, 19388–19391. doi: 10.26717/BJSTR.2020.25.004242

Zhang, J., Shen, X., Wang, Y., Jiang, M., and Lu, X. (2021). Effects of forest changes on summer surface temperature in Changbai Mountain, China. *Forests* 12:1551. doi: 10.3390/f12111551