Corpo Forestale dello Stato

Accademia Italiana
di Scienze Forestali

REGIONE TOSCANA

Sotto l'Alto Patronato del Presidente della Repubblica
Under the high patronage of the President of the Italian Republic

ATTI
del Secondo Congresso Internazionale di Selvicoltura
Progettare il futuro per il settore forestale

Firenze, 26-29 Novembre 2014

PROCEEDINGS
of the Second International Congress of Silviculture
Designing the future of the forestry sector

Florence, 26-29 November 2014

VOL. I

Accademia Italiana di Scienze Forestali
Firenze - 2015

A cura di / *Edited by*
Orazio Ciancio

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Gli Atti sono stampati grazie al contributo della Regione Toscana.

These Proceedings have been printed with the financial support of the Tuscany Region

Piazza Edison 11
50133 Firenze

ISBN 978-88-87553-21-5

CLIMATE CHANGE ADAPTATION STRATEGIES IN FOREST MANAGEMENT: USE OF A DECISION SUPPORT SYSTEM FOR A DISTRICT FOREST PLAN

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The forest planning understood as mere management of stands for wood production has currently lost, compared to the past, its relevance and application possibilities; therefore, it is necessary to focus on the multifunctional services of forests. Here we present a synthesis of a district forest plan which has been developed through five pillars: (a) mapping of potential forest ecosystem services, (b) involving local stakeholders and experts, (c) exploring strategic scenarios of forest yield, (d) mapping homogeneous forest zones, and (e) capitalising the knowledge of forest working plans. The experts contributed through a decision support system NetSyMoD (Network Analysis-Creative System Modelling-Decision Support) which helps the decision process in the assessment of the scenarios of forest yield. It was possible to appreciate that an increase of yield suits well to climate adaptation in some forest zone and with the contents of forest working plans. This approach may be replicated in other forest districts where there is an history in the application of silvicultural control methods.

Keywords: climate change, forest planning, decision supporting system, participative process.
Parole chiave: cambiamenti climatici, pianificazione forestale, strumento di supporto alle decisioni, processo partecipativo.

http://dx.doi.org/10.4129/2cis-ts-cli

1. Introduction

Because of changing climate and natural disturbance patterns in the last century (Auer *et al.*, 2007), forest tree species have altered their physiological behaviour (Lindner *et al.*, 2010). These two driving factors interact with land-use changes (Kulakowski *et al.*, 2011). To cope with these trends and to continue to ensure production, forest managers must adapt traditional silvicultural methods to guarantee the conservation of the diversity of species and ecosystems. Forest planning should fit the long-term consequences of changes in climatic, disturbance, and land use conditions through adaptive silviculture that focuses on tree species composition and stand structure for the provision of forest ecosystem services. Here we present a synthesis of a district forest plan which has been developed through four pillars: (a) mapping of potential forest ecosystem services, (b) involving local stakeholders and experts, (c) exploring strategic scenarios of forest yield, (d) mapping homogeneous forest zones, and (e) capitalising the knowledge of forest working plans.
The plan is intended to be the basis for the development and integration of the adaptation to climate change and land use in the forest operational planning. More detailed information can be found in Sitzia *et al.* (2014a) and Sitzia *et al.* (2014b).

2. Study area

The plan has been developed in the Boite forest district which is situated in the province of Belluno, Veneto region, in a valley of the Dolomites which has an extension of 41,013 ha divided in five municipalities. Altitudes range between 900 and 3,264 m a.s.l., whereas the rainfall range is 880-1,600 mm and the annual mean temperature ranges between -4°C and 8°C. Since 1960, potential forest productivity related to climatic conditions has increased in particular in the upper mountain belt and decreased in the valley bottom (Mariani and Parisi, 2014).
The main part of the district (70%) is covered by forests, mainly conifer communities, of which 95% is managed with working plans.
The economy of the valley, in addition to the relevance of the forestry sector, is based on tourism and small handcraft industries.
The management of the area since mid-twentieth century has been based on periodic inventories and on low-intensity shelterwood systems.

3. Potential ecosystem services and stakeholders preferences

Potential provision of five forest services (conservation, landscape, production, regulation, recreation) has been assessed based on a combination of site

capability and forest type suitability in each of 2,648 forest land units.
Stakeholders have participated in assigning priority to the five forest ecosystem services at the district level. Each stakeholder assigned, filling in a questionnaire, a score to the five services which has been used to weight the potential score for forest service provision and, finally, to derive a priority service on each of the forest land units.
On average, the stakeholders assigned the highest weight to the production service (Tab. 1). After a preliminary analysis, the recreation service resulted to be a priority only in two land units. Therefore, also on the basis of their evident relationships, recreation service was aggregated to the landscape service.

4. Strategic scenarios of forest yield

The forest inventorial data allowed us to precisely know the values of actual growing stock and annual increment.
The data showed an high growing stock combined with a low ration of yield to increment. We combined these values with optimal growing stock and three different adjustment periods of actual to optimal growing stock which correspond to three different scenarios of forest yield: (a) BAU (business-as-usual), maintaining the current trend of yield; (b) SOFT, gradually increasing the current trend of yield; (c) HARD, rapidly increasing the current trend of yield.
The strategies were scored by involving experts in the analysis of alternative adaptation measures and suitable solutions using a platform combined with a spatial tool (Network Analysis-Creative System Modelling-Decision Support).
During the process each user assigns a value in each box of a matrix to express expectations as to the performance of each strategic scenario of forest yield. The SOFT scenario scored the highest mean score of 77/100, the second was the BAU with 65/100 and the scenario less feasible was the HARD with a score of 62/100.

5. Application to a forest district plan

The scenarios have been applied through two main tools: (a) homogeneous forest zones, and (b) forest working plans synthesis.
We mapped 15 forest homogenous forest zones, which could include one or more forest types depending on their representativeness in the district.
The characteristics of each homogeneous forest zone are summarised in a fact sheet.
The fact sheet summarises priority and secondary ecosystem services as a synthesis of those identified for each analysed land unit. Many homogenous forest zones showed to have as a priority the production service.
Nevertheless, some zones were of high importance for their landscape service; for instance, mountain pine scrubs and typical larch woods. Others, as pioneer Arolla pine-larch woods and typical outer Alpine Scots pine woods were important for their conservation service.
These homogenous forest zones were described also by capitalizing the information collated within the forest working plans. These information completed or confirmed those regarding the needs for silviculture to adapt to climate change. For example, according to several authors (e.g. Hasenauer *et al.*, 1999), Norway spruce responded positively to increased temperature, with higher growth rates in the high-mountain belt (Fig. 1).
The forest working plan analysis showed that many high mountain Norway spruce stands are mature and requires regeneration felling (Fig. 2).
For this reason, the scenario that has achieved the highest score is perfectly in line with the desired adaptation to climate change.
In fact, managers need to take advantage of all the suitable conditions, socio-economic and ecological, to avoid that too large areas of this zone are mature or senescent and try to ensure an adequate structural and chronological equilibrium, carrying out, if necessary, thinning and encouraging the regeneration of mature stands.

6. Conclusions

This work allowed to consider the opinion of both stakeholders and experts, giving a spectrum of the feasibility of the plan and the forest yield possibilities of the district.
It is possible to appreciate that an increase of yield suits well to climate adaptation in some forest zone and with the contents of forest working plans.
This type of studies and the applied approach may be translated in other forest districts where there is an history in the application of silvicultural control methods.

Acknowledgements

The authors wish to thank Paola Bolzon, Dragana Bojovic, Thomas Campagnaro, Giovanni Carraro, Emanuele Lingua, Luigi Portoghesi, Andrea Rizzi, Giovanni Trentanovi and Sergio Zen who collaborated on the forest district plan and the municipalities, stakeholders, and experts who participated in the decision process. Regione del Veneto and University of Padova worked jointly within the C3-Alps project, cofunded by the Alpine Space programme.

Table 1. Average weight (0-1) given by stakeholders to five forest ecosystem services in the Boite district, Belluno Province, Italy.

Production	*Regulation*	*Landscape*	*Conservation*	*Recreation*
0.31	0.18	0.19	0.16	0.16

Figure 1. High mountain Norway spruce forest in Boite district, Pian de Loa, Belluno Province, Italy (photo by T. Sitzia).

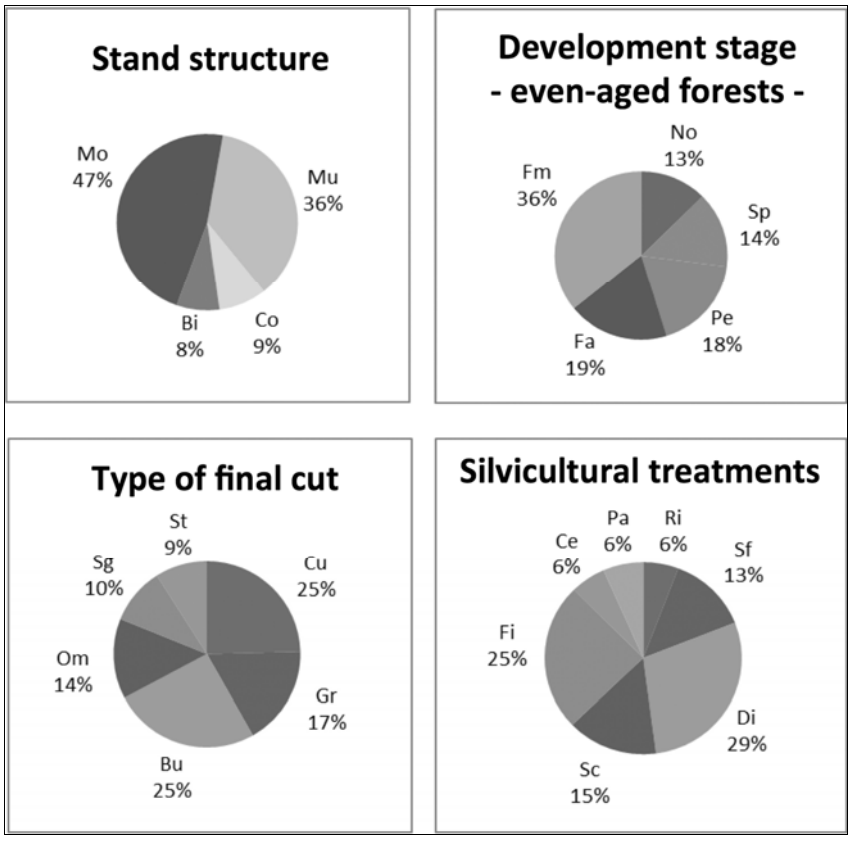

Figure 2. A detail of the fact sheet of the high mountain Norway spruce woods where management systems are summarised: stand structure (Mo: even-aged, Mu: uneven-aged, Co: irregular, Bi: two-layered); development stage of the even-aged series (Fm: mature, No: sapling, Sp: thicket, Pe: pole, Fa: adult); type of final cut (Cu: selection method, Bu/Gr: group-shelterwood, Om: wedge-shelterwood, St: strip-shelterwood, Sg: liberation); and silvicultural treatments (Ri: wedding, Sf: cleaning, Di: thinning, Sc: post-wind-thrown salvage, Fi: salvage and sanitation, Ce: transformation of dominated coppice to high-forest, Pa: control of pasture in woodland).

RIASSUNTO

Strategie di adattamento ai cambiamenti climatici nella gestione delle foreste: applicazione di un sistema di supporto decisionale ad un piano forestale comprensoriale

La pianificazione forestale intesa come mera gestione del soprassuolo arboreo ha perso la rilevanza e le possibilità di applicazione del passato; il concetto sul quale è opportuno concentrarsi attualmente è quello di multi-funzionalità.

Il presente articolo riporta una sintesi di un piano forestale distrettuale che è stato sviluppato attraverso cinque elementi cardine: (a) cartografia dei servizi eco-sistemici forestali, (b) coinvolgimento dei portatori di interesse e di un forum di esperti, (c) studio di scenari strategici di ripresa, (d) perimetrazione di zone forestali omogenee, e (e) capitalizzazione dei contenuti dei piani di assestamento forestale aziendali.

Il coinvolgimento degli esperti è avvenuto attraverso l'uso di uno strumento di supporto alle decisioni NetSyMoD (Network Analysis-Creative System Modelling-Decision Support) per facilitare il processo decisionale nella valutazione degli scenari di ripresa forestale.

Si è così potuto verificare che un moderato incremento della ripresa è compatibile con diverse misure di adattamento ai cambiamenti climatici, in alcune zone forestali omogenee, ed è anche in linea con il contenuto dei piani di assestamento forestali. L'approccio seguito può essere replicato in altri comprensori montani, dove si abbiano a disposizione diverse revisioni dei piani di assestamento forestale e si possa quindi fare affidamento sul periodico e preciso rilevamento dei caratteri biometrici delle foreste gestite.

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