Mixed Forest Definition for COST Action FP1206

FP1206 Management Committee
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Abstract
There is an increasing interest in mixed forest. In Europe, around 25% of forested land is considered as mixed according to FOREST EUROPE State of Forests' 2011. The common view of mixed forests as that composed of more than one tree species is different when other variables apart from the number of species are considered. Volume, basal area and canopy cover by species and their subsequent thresholds vary across Europe. The scale at which definitions work is also variable and ranges from plot to landscape level. However, in order to exchange experiences and sharing scientific knowledge regarding mixed forests a common definition for the Aims of the Action is needed. In this report the Management Committee will give a consistent definition of mixed forest based on compositional, structural and developmental characteristics. Additionally, the need for a functional assessment and spatial- and time-scale dependency of mixed forest classification is discussed

Keywords
EuMIXFOR — Europe — Composition — Structure — Development

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Introduction

COST Action FP1206 is aimed at establishing a long-lasting network on mixed forests. This apparently easy task is hurdled by the lack of a consistent definition of mixed forests. In spite of great efforts in the past in defining and classifying mixed forests (Leikola 1999) there is not a common definition valid across Europe. The large climatic variability and types of admixtures in the continent has lead to local definitions. The interest for mixed forests stems from the ideal conception of Gayer and close-to-nature management that has been revisited along the silviculture history of Europe (Gamborg and Larsen 2003). More recently the extension of forest as complex ecosystems has promoted the ecosystem management approach in forestry (Kimmins *et al.,* 2010).

The difficulty in the definition of mixed forest stem from both terms: forest and mixed. For a start in this COST Action we will adopt the definition of forest proposed by FAO and modified by COST Action E43 (Lanz *et al.,* 2010): "Forest is land spanning more than 0.5 ha, with trees bigger than 5 m of a crown cover of more than 10%, or with trees able to reach these thresholds in situ. It excludes areas fulfilling the thresholds specified above but with a maximum width of less than 20 m, and land predominantly under agricultural or urban use. It includes temporary unstocked stands like natural regenerated areas, young plantations and areas with a natural or a plantation, expected to (be) install(ed) within 10 years after removal of the old stocking, which will be able to reach forest thresholds at maturity".

This report will concentrate in the definition of 'mixed' or 'admixture of species' in forests. First, previous definitions of mixed forests are presented including those proposed by National Forest Inventories (NFI) in contributors countries and those found in the literature. Secondly, the functionality of mixed forests and the temporal and spatial scale is discussed. Finally a definition of mixed forest approved by the Management Committee for the purposes and aims of this action is presented.

1. Classifications and definitions of mixed forests

There are at least three categories of definitions of mixed forests: those based on species composition, those based on structural features and those based on forest development phases.

1.1 Compositional definition

The starting point for a mixed forest is the trivial fact that there must be at least two tree species. However, it follows that the proportion of species on the basis of composition can differ depending on the species presented. Toumey and Korstian (1947) defined pure stands those where 80 percent or more of the overstory is of a single species. However, if less than 10 percent in the overstory is of a commercially or selviculturally valuable species the stand is classified as mixed. These authors provide the example in table 1 of different pure vs. mixed classification for North America. Depending on the contributing species the ratio between species may differ greatly.

Table 1. Species effect on mixed forest classification

White pine	Beech	Grey Birch	Classification
95%	5%		Mixed Stand
80%		20%	Pure white pine stand

In the most recent attempt to define mixed forests in western Europe Olsthoorn *et al.,* (1999) extended the compositional definition with a reference to spatial scale and species interaction: 'stands composed of different tree species, mixed on a small scale, leading to competition between trees of different species as a main factor influencing growth and management'. However, other species interactions occurs in mixed forests and they seem to be excluded from the definition.

1.2 Structural definition

Leikola (1999) presented a classification of mixed forest based on Langhammer (1971) that implicitly gives a sort of definitions of mixed forests based on form, type and grade of mixtures. The **form** is related to horizontal pattern of trees in a stand which can be stem-wise or by individuals, row-wise or group-wise; the **type** refers to the vertical distribution of trees in single- or multi-storied stands indicating that 'in the strict sense' only trees belonging to the same storey build up a mixed forest and finally the **grade** refers to the number and amount of tree species in a stand (compositional definition).

1.3 Developmental definition

Forest development is a complex function of factors like disturbance regime, environmental gradients or species composition (Spies 1997). In any of the existing models of forest or stand development there are two repeated concepts: transition and stratification.

The idea of transition appears in late developmental phases where changes in species composition and structure occur. However, for both compositional and structural definitions of mixed forests this transition or temporary of mixture is not taken into account.

For management purposes the stratification is the core concept of mixed forest silviculture that operates at the stem-exclusion developmental phase (Oliver and Larson 1990). Smith *et al.,* (1997) classified mixed forests in **single-cohort stratified mixtures** and **mixed, multicohort stands**. The former case comes from natural regeneration after a major disturbance or from a planned plantation. In this kind of mixed forests competition is harder intra-species and stratum rather than inter-species (the so called 'competitive production principle' Vandermeer (1989) in Scherer-Lorenzen *et al.,* (2010)). In other words, the lower strata is not excluded.

The second mixed forests proposed is considered far from the ideal J-shaped curve for balanced all-aged condition, which is for these authors a creation of silvicultural actions rather than a natural random process (Smith *et al.,* 1997, pg. 36). Finally, **Mixed single-canopied stands** is defined as that consisting of two species growing in height at the same rate. This kind of mixed stand is not common and when it occurs is a temporary situation until one species suppress the other.

1.4 National Forest Inventory Definitions

The increasing interest in the assessment of forest resources have improved the harmonisation of National Forest Inventories (NFIs) across Europe (Tomppo *et al.,* 2010). However, there is not a common definition for mixed forests and there are three kind of approaches in NFI to deal with mixed forests.

1. No definition: A simple list of species' name and their biometrics is recorded
2. Percentage canopy cover definition
3. Dendrometic-Sharing based definition (not based in canopy projection)

Although definitions based on percentage of canopy cover and dendrometic-sharing seems to be easy to compare across countries the reality is that it is very difficult. In the case of percentage canopy cover a minimum plot surface is required as well as a percentage limit. Some examples are Austria with 300 m^2 and 80-20% of cover sharing, Ireland uses the same minimum cover but the plot area is larger (500 m^2). France expands the minimum area to approximate 0.2 ha and 75-25% of sharing and Spain uses the same plot surface as France but the minimum cover for a species is 30%. There are NFIs that do not specify the minimum plot surface and only gives minimum occupancy of canopy cover for one of the existing species (United Kingdom:20%; Lithuania: 15%; Portugal:25%; Norway: 30% in young stands).

In the case of dendrometric-sharing the difficulty of comparison is even greater as there are different biometrics measured like volume (Bulgaria, Finland, Norway in older stands, Turkey, Serbia), basal area (Belgium, Slovakia, Switzerland,

Sweden) or number of stems per hectare (Algeria, Sweden if trees are smaller than 7 m height) and their subsequent thresholds for each variable. The difficulty can reach paroxysms proportions as volume is not defined equally (total volume, stem volume or commercial volume) and basal area is even measured at different stem height (1.3 or 1.5 m). The minimum diameter or circumference inventoried is another variable to take into account.

For those countries without a comprehensive mixed forest definition the situation is similar as can co-exist different definitions for management purposes.Much of the national forest inventory (NFI) definitions are based on structural description. In any case, such definitions can be considered needed but not enough to describe mixed forests.

2. Is needed a functional assessment?

All the previous definitions are a continuum as they share common attributes: Developmental definitions contain structural and composition definitions and structural definitions include compositional features. Consequently, irrespective of compositional, structural or developmental stages the term 'mixed' is always used when at least two species co-occur in the same defined area. This confer tree species richness a pre-eminent role in the definition. However, there is a certain functionality limit in the definition of mixed forests as species co-occurrence or tree species richness might not necessary mean functional differentiation. Oliver and Larson (1990, page 150) indicate that species with similar growth patterns can interact as a single species. Such behaviour is known in ecology as functional redundancy (de Bello *et al.,* 2007) which can be a mechanism explaining the lack of a strong biodiversity effect on ecosystem functioning (Paquette and Messier 2011).

If we want to consider an ecosystem functioning point of view in the definition of mixed forest we should incorporate the main mechanism that does (or does not) control biodiversity-productivity relationship in mixed forests. Two hypothesis try to explain the positive diversity effect (Brassard *et al.,* 2011): the species complementary hypothesis (facilitation and niche differentiation) and the selection effect hypothesis. Paquette and Messier (2011) showed that complementary effects are less important in favourable habitats where competition is the main driver of biodiversity-productivity relationships. Under this situation the definition of Olsthoorn *et al.,* (1999) is only applicable to mixed forests growing in good sites. Thus, a complete definition of mixed forest should include other plant interactions than competition alone.

A functional assessment of a mixed forest needs to take into account tree functional groups based on different criteria (Köner, 2010). Some examples are succesional stage, native vs. exotic, light/shade tolerance, crown architecture or maximum rooting depth. Although these criteria are variable and often hard to measure, functional traits richness instead of species richness should be preferred to define ecosystem processes (Scherer-Lorenzen *et al.,* 2010).

3. Does spatial and temporal scale matters?

In any of the above definition it has been overlooked that a key concept in forest management can fail in describing mixed forests. A stand has been defined as 'a well-demarcated portion of wood-land having a uniform structure and sufficiently limited in extent to permit a certain thinning treatment to be independently applied' (Assmann 1970, page 208) or as 'a group of trees relatively homogeneous in age, structure, composition and site conditions' (Smith *et al.,* 1997). These definitions produce different outcomes in terms of mixed forest area. If the occurrence of the species is consorting (species are equally present) by individuals both definitions can classify the same area (or group of trees) as mixed. However, if the occurrence of the species is concomitant (species are not equally present, one is subordinated) by individuals the definition provided by Assmann would classify the stand as mixed as long as the area is sufficiently limited to apply a thinning treatment, whereas the definition provided by Smith would or would not classify it as mixed depending on the degree of 'homogeneity of composition' in the group of trees. On the contrary, if the mixture is consorting by groups or concomitant by groups Assman's definition would classify such a stand as mixed if groups are located within the extension, whereas Smith's definition would classify it at mixed if the group of trees comprise all groups presented. A definition of stand based on area rather than on groups of trees will produce more mixed forests. But, how large is 'sufficiently limited in extent'? Is it valid the term of stand in mixed forests?. The spatial variability of species mixture is larger from plots to landscape level, so would it be necessary to fix the spatial scale first?.

The same applies to the temporal definition of mixed forest. A mixed forests, would it be 'mixed' in the near future?. Would the mixture, measured as proportion, be the same?, how can affect forest dynamics a change in the degree of mixture?. Some of these questions have been partially answered in terms of development phases as mixed forests occurs in late developmental phases of stands originated by single-species (Larson 1992) and that variation of species proportion in the course of time can affect dynamics of mixed forest (Puettmann *et al.,* 1992; Weiskitel *et al.,* 2009). However, none of the definitions found dealt with spatial or temporal issues.

4. A consistent definition of mixed forest

It is a difficult task to reconcile all points of view to describe mixed forests into a single one. Compositional and structural base definitions are the easiest features to describe a mixture of tree species in a forest, although it would be desirable in both cases to add spatial limits. Developmental definitions are difficult as in large forested areas is plausible to have several stages. In addition, a perfect knowledge of the disturbance regime, either natural or human-induced, that has lead to the current situation is required. The inclusion of func-

tional aspects in a definition should be based on biodiversity-productivity relationship as identification of competition or complementarity effects can alter management prescriptions.

Thus, a 'perfect' definition should include all aspects described here plus the economic and social dimensions of forests. The following definition was approved by the Management Committe of the Action in Madrid on October 23rd, 2013 and it was considered valid for all working groups in the Action:

A mixed forest is a forest unit of at least 0.5 ha, excluding linear formations, where at least two tree species coexist at any developmental stage sharing common resources (light, water, and/or soil nutrients). The presence of each of the component species is normally assessed as a proportion of the number of stems or of basal area, although volume, biomass and canopy cover may be used for specific objectives. A variety of structures and patterns of mixtures can be perceived to occur, while the interactions between the component species and their relative proportions may change over time.

In order to compare research results when classifying a mixed forest it should be needed to state the dimension of the forest unit (plot, stand, forest, landscape) the developmental stage (initiation phase, stem-exclusion, transition, old-growth), the occurrence and form of mixture (consorting, concomitant, stem-wise, group-wise) the temporal dimension of the study (static, dynamic) and the main driver of diversity-productivity relationship (facilitation, niche differentiation, competition). In this COST Action we are aimed at looking inside these features.

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