TREE REGENERATION SUCCESS IN RESPONSE TO CANOPY OPENING AND SITE PREPARATION: IMPORTANCE OF DIRECT AND INDIRECT PLANT INTERACTIONS IN SUBMONTANE FOREST STANDS.

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Introduction

Regeneration success is affected by many environmental factors that act in combination. Manipulating these factors through silvicultural operations may ensure regeneration success. The study focuses on the regeneration of forest stands located in the submontane area in northeast France. In these stands, natural regeneration is difficult and may extend over long periods (up to several decades) if no appropriate silvicultural operations are performed.

The present study aims at evaluating alternative methods for vegetation control and site preparation. These methods manipulate environmental factors that affect seedling establishment such as competition from the neighbouring plants (adult stand and vegetation), seed availability and soil characteristics. The primary objective of the study is to estimate the relative importance of seed rain, competition from the adult stand and competition from neighbouring vegetation on seedling abundance. The secondary objective is to compare the effects of various silvicultural methods (canopy closure control and site preparation) on regeneration success. Mechanical, chemical and biological site preparation methods were implemented in combination to a gradient of canopy opening in two forest stands. The stands differed in their fertility, which induces different vegetation dynamics between the two stands. Vegetation cover and tree seedling abundance were monitored for four years following treatments, and were analysed to assess the effects of the various factors on regeneration success.

Material and Methods

Mechanical, chemical and biological site preparation methods were implemented in combination to a gradient of canopy opening in two forest stands. A monospecific beech, *Fagus sylvatica*, stand (PP site) and a mixed silver fir-beech, *Abies alba*, *Fagus sylvatica*, stand (WE site) with contrasted vegetation communities were selected for the study. The stands differed in their fertility, hence different vegetation dynamics between the two stands.

On each site, 25 m x 25 m plots were established (10 and 12 plots in PP and WE sites, respectively). In each site, half of the plots were thinned over the entire plot and left unthinned around the plot. The other half of the plots were left unthinned.

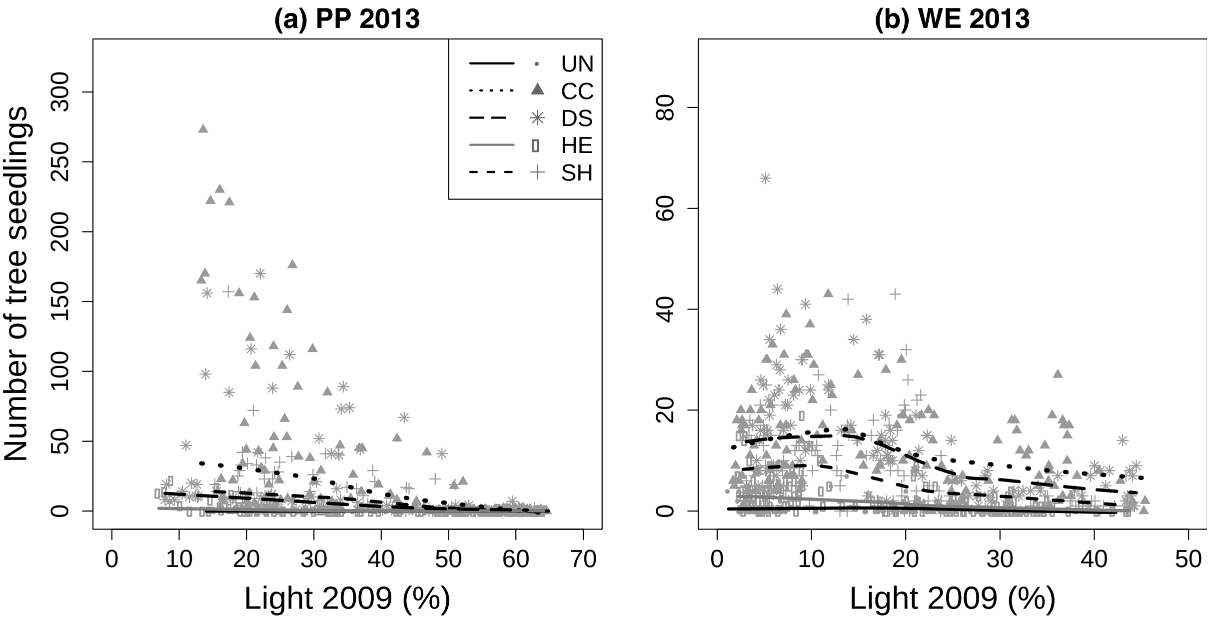
Each plot was divided into five parallel strips (5 m x 25 m). In the thinned plots, the strips were extended a few meters into the unthinned part of the stand. In each plot, each strip was assigned to one of the following site preparation method: (1) UN (untreated strip), no site preparation, vegetation and soil undisturbed; (2) HE (herbicide), glyphosate application (2160 g ha^{-1}) performed in June 2009; (3) SH (surface hoeing) using a hoe (Pioche Herse®, Kirpy, France) mounted on a mini excavator, performed in April 2009. The hoe removes the vegetation and hoes the soil down to 25 cm deep; (4) DS (deep scarification) using a scarifier (Scarificateur Réversible®, Kirpy) mounted on a mini excavator, performed in April 2009. The scarifier removes the vegetation, extracts the root systems and fractures the soil structure down to 40 cm deep; (5) CC (cover crop) sowing of a mixture of selected herbaceous plant species (*Alliaria petiolata*, *Digitalis purpurea*, *Galium odoratum*, *Hypericum perforatum*, *Myosotis sylvatica*, *Senecio ovatus*, *Silene nutans*, *Stellaria holostea*). Before sowing, surface hoeing was applied as in the SH treatment and, in September 2009, the soil was slightly scratched using hand tools and the mixture was hand-sown (seed density: 1 g m^{-2}).

From 2010 to 2013, vegetation cover and tree seedling abundance were monitored every year in ten to twelve 1m^2 subplots that were established in each strip (for a total of 535 and 660 subplots in the PP and WE sites, respectively). Relative Light Intensity (*RLI*) above each subplot was assessed in June 2009, using hemispherical photographs**.**

Results and discussion

In both sites, the primary factor that affected regeneration success was the physical barrier provided by neighbouring vegetation that prevented tree seed germination (Fig. 1). Herbicide application, that killed vegetation but did not remove dead plant biomass, allowed very limited seedling establishment.

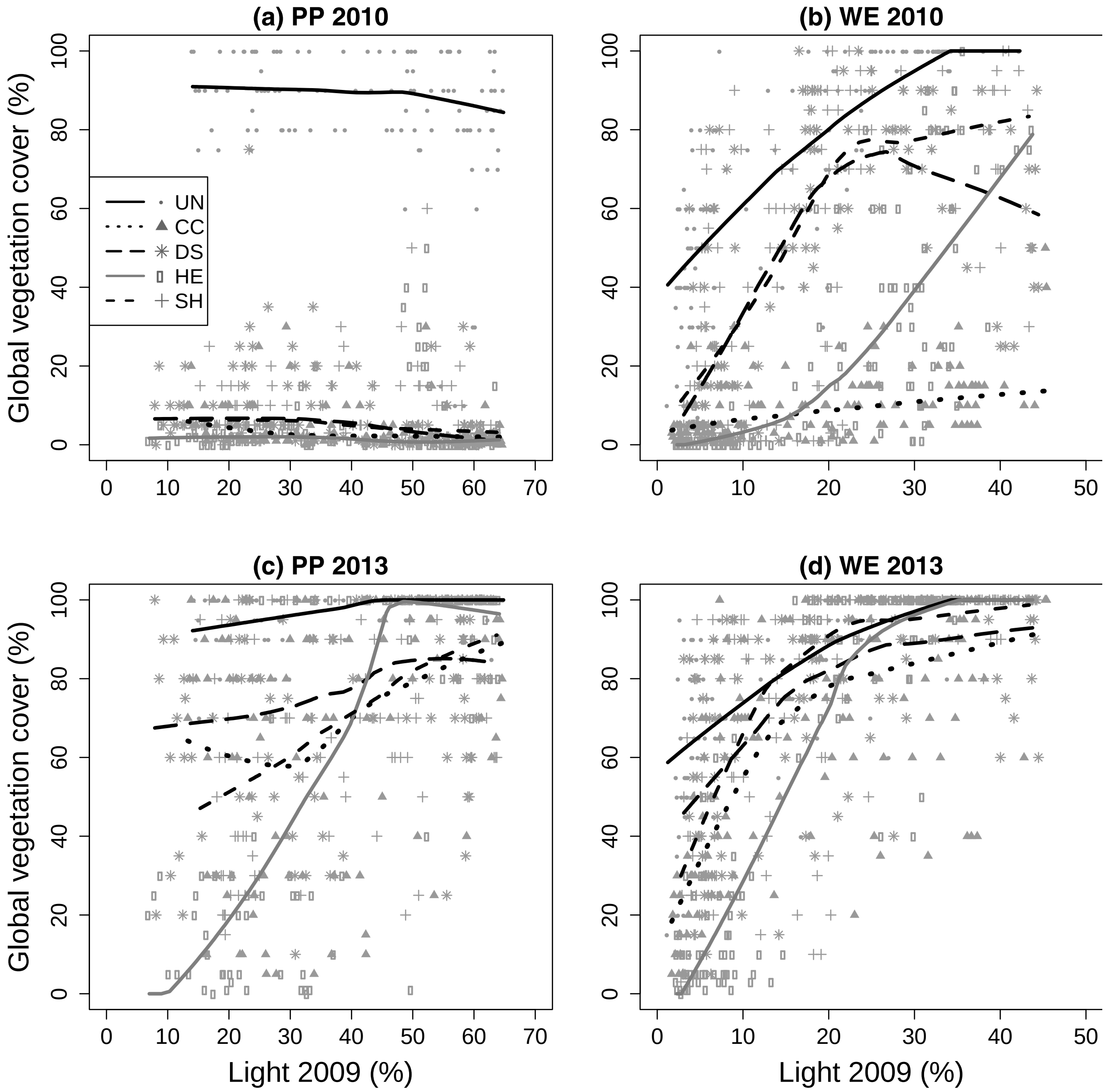
Fig1. Relation between the seedling density estimated in 2010 and light (measured in 2009) for the PP (a) and WE (b) sites. Lines (smoothing function) represent the tendency in each treatment.



The second factor that affected regeneration success was the seed rain. Plots close the adult stand or below the stand, which were submitted to intense competition from the stand but which benefited from abundant seed rain, had the highest seedling density (Fig. 1).

Vegetation dynamics strongly differed between the two sites (Fig. 2), vegetation colonisation was more rapid in WE site than in PP site. However, when looking at regeneration success, treatment comparisons within each site were similar for both sites. Seedling density slightly decreased during the four years of the study, in all treatments from both sites. However, treatment ranking did not change between the first year and the fourth year, showing the importance of the initial conditions (data not shown).

Fig2. Relation between global vegetation cover estimated in 2010 and in 2013 and light (measured in 2009) for the PP (a, c) and WE (b, d) sites. Lines (smoothing function) represent the tendency in each treatment.



In these low-mountain forest stands where natural regeneration had been blocked for decades, soil preparation (deep or surface scarification) is required to ensure seed germination. Almost no regeneration occurred in the untreated plots. Small canopy opening are recommended, but should not be too large to allow abundant seed rain and to provide a natural control on the development of neighbouring vegetation.

Light weighted tools provided adequate soil preparation and were easy to use in these low-mountain sites, where high slope (up to 50%) and high density of seed trees and rocks would prevent the use of large and heavy machines. Cover crop sowing after soil preparation led to higher seedling density after four years than all other methods.