BETA
Bureau d'économie théorique et appliquée

Documents de travail

« Adapting forest management practices to climate change: Lessons from a survey of French private forest owners »

Auteurs

Julie Thomas, Marielle Brunette, Antoine Leblois

Document de Travail n° 2021 – 05

Février 2021

Bureau d'Économie Théorique et Appliquée
BETA

www.beta-umr7522.fr

@beta_economics

Contact :
jaoulgrammare@beta-cnrs.unistra.fr

Université de Strasbourg
cnrs
Université de Lorraine
INRAE
AgroParisTech

Adapting forest management practices to climate change: Lessons from a survey of French private forest owners

Thomas J.[1], Brunette M.[2], Leblois A.[3]

February 4, 2021

Abstract

Climate change seriously impacts forest ecosystems. In order to maintain forest cover, adaptation strategies should be implemented. In France, adaptation decisions are mainly in the hands of private forest owners. However, little is known about the way they perceive climate change or about their decisions related to adaptation. The aim of this article is precisely to obtain such information through a survey conducted among more than 900 French private forest owners. We identified determinants to the adoption of adaptation (gender, area, profession, having a management document, perception of climate change impact). More importantly, we show that the decision of adaptation should not be thought of in general but strategy-by-strategy because we identified strategy-dependent drivers. The article concludes with a discussion about the public policy implications of the results.

Keywords: adaptation, forest, survey, French private forest owners.

JEL codes: Q23 (Forestry); Q54 (Climate • Natural Disasters and Their Management • Global Warming)

[1] Université de Lorraine, Université de Strasbourg, AgroParisTech, CNRS, INRA, BETA, France; Centre National de la Propriété Forestière (CNPF).

[2] Corresponding author: Université de Lorraine, Université de Strasbourg, AgroParisTech, CNRS, INRA, BETA, France. marielle.brunette@inrae.fr; Associate researcher Climate Economics Chair (CEC), Paris, France. ORCID ID: 0000-0001-8192-4819

[3] CEE-M, Univ Montpellier, CNRS, INRAE, Montpellier SupAgro, Montpellier, France; Associate researcher Climate Economics Chair (CEC), Paris, France. ORCID ID: 0000-0003-0504-884X

1. Introduction

Climate change will have serious impacts on forest ecosystems, altering the provision of goods and services worldwide. The increase in temperature and reduction in the precipitation regime will affect growth and productivity and will result in decline and mortality (Bergh et al. 2003; Jump et al. 2006). In the same way, the increase in frequency and intensity of natural events (Flannigan et al. 2000; Fuhrer et al. 2006) suggests large losses in the coming years. Forest disturbance damage in Europe has increased throughout the 20th century (Schelhaas et al. 2003) and has continued to rise in the first decade of the 21st century (Seidl et al. 2014) mainly due to climate change (Seidl et al. 2011). Damage from wind, bark beetles and forest fires is likely to increase further in coming decades, and the rate of increase is estimated at $+0.91 \times 10^6$ m^3 of timber per year until 2030 (Seidl et al. 2014). In France, where the forest cover encompasses 31% of the territory with a total of 16.8 million hectares (IGN 2016), and where the forest sector directly employs 378,000 people, for an added value of €25 billion and representing 1.1% of the French GDP (VEM 2017), these impacts may be detrimental.

The speed of environmental changes is such that implementation of adaptation strategies by foresters is required to maintain a forest cover (Spittlehouse and Stewart 2003). In this context, a wide range of adaptation strategies are recommended: reduction of rotation length, reduction of density at the time of plantation, adoption of species better adapted to the future climate, species mix, uneven-aged stands, etc. (Spittlehouse and Stewart 2003). However, to implement adaptation, foresters must be aware that climate change is actually occurring, they must perceive the threat that climate change represents for their forests, and they must be able to make decisions, often irreversible, to allow forest adaptation.

In the framework of international negotiations about climate change, forests have a main role to play in terms of mitigation. Public authorities are thus under pressure to implement policies and projects that facilitate adaptation (Van Aalst 2006; Hochrainer-Stigler et al. 2014). However, little information exists about the French foresters' adaptation decisions, whereas information is required to implement relevant public policy.

In this context, many research questions have emerged: Are French foresters aware of climate change? How do they perceive the impact of climate change? Have they already modified their management practices? If yes, which adaptation strategies have they adopted and why? If not, why choose to not adapt?, etc. More generally, we address the question of the determinants of the adaptation decisions of French foresters in order to identify levers to encourage them to adapt.

Forest adaptation towards climate change has been widely addressed in the literature. Several economic methodologies have been put into practice. For example, some articles have used cost-benefit analysis to study the economic relevance of some adaptation strategies: adoption of better-adapted tree species (Hanewinkel et al. 2013; Brunette et al. 2014), species mixture (Yousefpour and Hanewinkel 2014), reduction of rotation length (Bréda and Brunette 2019), near-natural forestry (Schou et al. 2012), among others. The main conclusion is that, in general, implementation of an adaptation strategy appears relevant from an economic point of view in comparison to business-as-usual. Some papers also compared different adaptation strategies (Jönsson et al. 2015; Brèteau-Amores et al. 2019), and found that a combination of strategies may be the best option in economic terms. Another widely used methodology is surveys to better understand individuals' behaviours. The first surveys were about perception of climate change with no direct link to the forester's adaptation decision, such as, for example, in Blennow et al. (2012) and Eriksson (2014). Other surveys directly questioned the foresters about potential adaptation options (Ogden and Innes 2009; Lidskog and Sjödin 2014). The last category of articles attempts to link both the perceived climate change and adaptation decisions. Using a "paper and pencil" survey, Yousefpour and Hanewinkel (2015) questioned 262 German forestry employees working in either public or private forests or for state authorities about the perceived impact of climate change, adaptive forest management and the potential of forestry to mitigate climate change. They showed that most of the respondents perceive climate change as real, human-induced, and significant. They also reported that adaptation strategies like using better-adapted tree species and origins were mainly perceived as helpful. Through an online survey of 391 forest owners and managers from Belgium, Sousa-Silva et al. (2016) studied how they perceive the role of their forest management in the context of climate change and the impediments that limit their ability to prepare and respond to these changes. They show that most of the respondents are aware of the changing climate, although only one third of them said that they had changed their practices to address climate change. The main brake to this implementation was the lack of information. Using data from online surveys of 1131 forest owners and managers from seven European countries (203 respondents from France), Sousa-Silva et al. (2018) assessed how they perceive their role in adapting forest management to climate change. The surveys deal, among other things, with the impacts of climate change and the way foresters consider climate change in their management decisions. Their main conclusion is that results are country-dependent with variability in terms of perceptions and actions. They identified some relevant actions such as species mix and assistance in tree regeneration. They also found that the French foresters (along with the Slovakian ones) are among the most numerous to have undertaken adaptation strategies. Brunette et al. (2020) focused on the role of risk aversion in the forest adaptation process of 88 forestry professionals from France and Germany. They addressed both the propensity and the intensity of adaptation, and identified risk aversion as a new obstacle to adaptation. They confirmed that species mix and assistance in tree regeneration are prioritised by foresters.

On the basis of this short literature review, several comments can be made and make it possible to justify our article. First, the nature of ownership is very important when dealing with adaptation to climate change because it determines the actors that make decisions and act in the field. While most of the literature evoked above deals with samples of forest owners, forest managers and/or forestry professionals from the private and/or public sector, the relevant decision unit in France is the private forest owner. Indeed, France is an exception in Europe because 75% of the forest area is privately owned by 3.3 million private forest owners. Better knowledge of this population in terms of perceptions and actions towards climate change is a prerequisite towards an efficient adaptation plan. Second, French foresters are rarely considered, and when they are, they are rarely private forest owners and the number of respondents is not very high - 203 in Sousa-Silva et al. (2018) and 49 in Brunette et al. (2020) - and the individuals are randomly selected (no representative sample), probably due to the way data are collected (paper and pencil, online). Third, the literature converges towards the idea that some adaptation strategies seem to be prioritised or will be prioritised in the future by the foresters, like the increase in the species mix and assistance in tree regeneration (Sousa-Silva et al. 2018; Brunette et al. 2020), or the use of better-adapted tree species and origins (Yousefpour and Hanewinkel 2015). However, to our knowledge, no article has yet to explain what the determinants are that encourage foresters to adopt one of these strategies rather than another.

In this context, we propose to analyse the French private forest owners' revealed behaviours when faced with climate change, and their choices in terms of adaptation. For that purpose, we ran a phone survey with 960 respondents, selected by plot size and region using a stratified sampling method, in eight regions and four forest area classes. Descriptive statistics make it possible to characterise French private forest owners, their property, the way they perceive climate change and their adaptive capacity. We used probit regression to identify the determinants of the adaptation choice. In addition, the high number of respondents allows us to run a probit regression per adaptation strategy to identify strategy-dependent determinants. We confirm some classical results from the literature, and we also provide new insights in order to improve knowledge about French private forest owners' adaptation decisions. In particular, we show that variables like gender, area, profession, having a management document and the perception of climate change impact are significant determinants of the adaptation decision. More importantly, we show that the decision of adaptation should not be thought of in general but adaptation-by-adaptation because we identified strategy-dependent drivers. We discuss the results in light of potential public policy implications.

The rest of the paper is as follows. Section 2 presents the materials and methods used. Section 3 describes the results, and Section 4 is devoted to a discussion about them. Section 5 concludes the article.

2. Materials and Method

2.1 Questionnaire design

The qualitative survey was conducted in 2018 on 944 private forest owners from metropolitan France by the Research Centre for the Study and Observation of Living Conditions (CREDOC). It consisted of a phone survey with 37 questions that took approximately 10 minutes to answer.

The questionnaire was composed of different parts, as indicated in Figure 1.

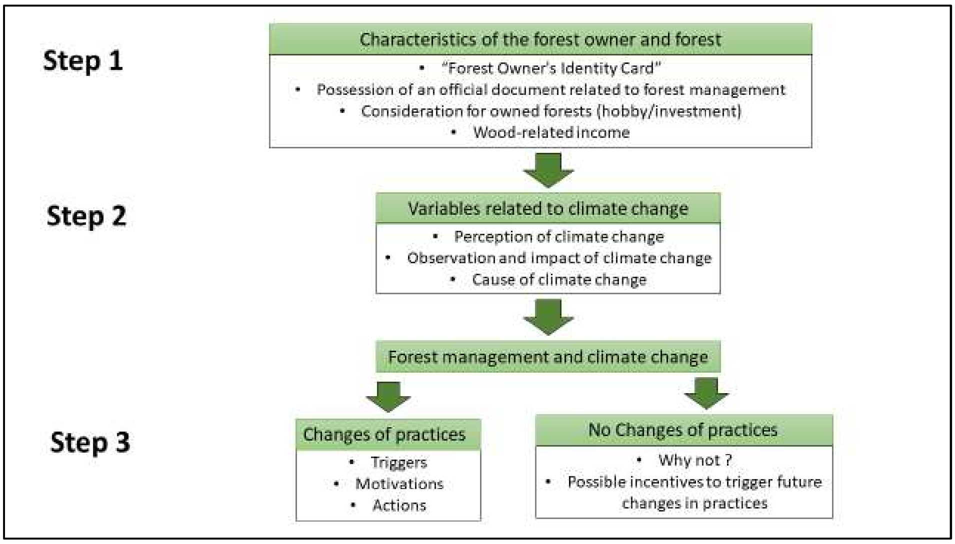

Figure 1. Schematic representation of the questionnaire.

The first part of the questionnaire is dedicated to the characteristics of the forest owner and the forest. The second part deals with variables related to climate change (perception, impact, cause), and the last part with changes in the practices (already implemented or not, reasons, motivations, type of actions).

2.2 Sampling

The sample was drawn up from a double stratification, by region and area class.

We randomly selected the same numbers of potential respondents for each region. We thus had eight regions (vs. 13 in the official sub-national divisions. This was due to the groups of regions made on the basis of representativeness of forest management by the French National Centre for Private Forest Owners) represented by approximately equal samples in each one: (1) Auvergne-Rhône Alpes (119 respondents), (2) Corse-Provence-Alpes-Côte d'Azur-Occitanie (114), (3) Bourgogne-Franche Comté (119), (4) Grand-Est (119), (5) Centre-Val de Loire-Ile de France (112), (6) Nouvelle Aquitaine (117), (7) Bretagne-Pays de Loire (123), (8) Hauts de France-Normandie (121).

We considered four forest area classes: from 4 to 10 ha, from 10 to 25 ha, from 25 to 100 ha, and more than 100 ha. The distribution was as follows: 314 owners in [4-10 ha], 161 in [10-25 ha], 399 in [25-100 ha] and 70 in >100 ha].

2.3 Econometric strategy

In the first step, we ran a probit regression on a binary variable, taking the value of 1 for forest owners who had already begun adaptation, and 0 otherwise (no adaptation). We then created a variable *Change_practices* that encompassed all the forest owners who had adopted adaptation strategies in the past, both in the past five years and before. This regression allowed us to identify the determinants of the private forest owner's decision to adapt.

In the second step, we ran a probit regression per adaptation strategy, among the five included in the survey. This regression aims to highlight potential strategy-dependent drivers that can only explain some strategies and not the general decision of adaptation.

Three models were run for each regression: a regression with a clustering at the department level, a regression with a clustering at the department level and regional fixed effects, and a regression considering a clustering at the inter-regional level and regional fixed effects. Standard errors are more robust when clusters are large, and coefficients more precise with a lower level of fixed effects, which makes the third regression the most robust.

3. Results

3.1 Descriptive statistics

Table 1 presents the descriptive statistics related to the first part of the questionnaire, the characteristics of the forest owner and of the forest. Table 2 presents the variables of the second part of the questionnaire about climate change. Finally, part 3 of the questionnaire is presented in Table 3 with the decisions in terms of adaptation.

Our sample is mainly composed of middle-aged men (45 to 65 years old). They show very heterogeneous education levels, with well-represented extremes: a large proportion of the sample has an education level lower than A level and the second largest share reached a master's degree. The two most highly represented socio-professional categories (*SPC*) are farmers and executives.

Regarding the characteristics of the forest, we can observe that the average forest area owned in our sample is about 40 hectares, with a large variability: minimal area of 4 hectares and maximal of 2300 hectares. Most of the forest owners have forests of between 4 and 100 hectares; very few (less than 1%) own more than 100 ha. Private forest owners mainly own their forests for biodiversity conservation (*Obj_Biodiversity*) and leisure-related reasons (*Obj_Leisure*), although the answer to such a question could be relatively sensitive. Among the seven possible main reasons for owning forests, owners selected 4.5 of them on average, confirming the multi-functional characteristics of French forests and the non-specialisation of French forestry.

Table 1. Characteristics of the private forest owners and of the forests.

Variable	Mean	Std. Dev.	N
FORESTER			
Gender (female = 1)	0.078	0.269	944
Age < 44 years	0.034	0.181	944
45-65 years	0.682	0.466	944
> 65 years	0.284	0.451	944
Education: No diploma	0.055	0.229	944
< A level	0.416	0.493	923
A level	0.132	0.339	923
2 to 3 years after A level	0.192	0.394	923
Master	0.205	0.404	923
SPC: Never worked	0.014	0.117	944
Farmer	0.329	0.47	944
Artisan	0.132	0.339	944
Superior (executive)	0.256	0.437	944
Intermediary	0.127	0.333	944
Employee	0.07	0.255	944

Worker (factory)	0.071	0.257	944
FOREST			
Area (Min = 4.012 ha; Max = 2300.48 ha)	39.806	94.267	944
4-10 ha	0.333		944
10-25 ha	0.171		944
25-100 ha	0.423		944
> 100 ha	0.074		944
Objective: Obj_Affection	0.005	0.073	944
Obj_Heritage	0.005	0.073	944
Obj_Fiscal/Tax	0.001	0.033	944
Obj_Hunting	0.008	0.092	944
Obj_Timber	0.048	0.213	944
Obj_Biodiversity	0.109	0.312	944
Obj_Leisure	0.823	0.382	944
Manag_document	0.49	0.5	922
Revenue_12months	0.436	0.496	913
Among which: Revenue_logging	0.518	0.5	398
Revenue_ hunting	0.359	0.48	398
Revenue_other	0.123	0.329	398
Regions: Auvergne-Rhône-Alpes	0.126	0.332	944
Bourgogne-Franche-Comté	0.126	0.332	944
Bretagne-Pays de la Loire	0.130	0.337	944
Centre-Val de Loire-Ile de France	0.119	0.324	944
Corse-PACA-Occitanie	0.121	0.326	944
Grand Est	0.126	0.332	944
Hauts de France-Normandie	0.128	0.334	944
Nouvelle Aquitaine	0.124	0.33	944

Approximately half of the people in the sample own at least one formal document for forest management and public regulation (*Manag_document*). The three documents considered are: “Plan simple de gestion”, “Règlement type de gestion”, and “Codes des bonnes pratiques”. When owners hold more than 25 hectares of forest, they have to provide a “Plan simple de gestion”. It is mandatory by law and well enforced.

Finally, for 44% of the private forest owners, forest brings revenue over the last 12 months (*Revenue_12months*) and mainly from logging (51.8%).

The number of respondents is almost identical in each of the eight regions considered, approximately 12% of the sample in each region.

Table 2. Climate change variables.

Variable	Mean	Std. Dev.	N
Perception: Yes	0.304	0.46	944
Somewhat yes	0.43	0.495	944
Somewhat not	0.103	0.304	944
Not at all	0.078	0.269	944
Don't know	0.085	0.279	944
Anthropic: Yes	0.466	0.499	693
Somewhat yes	0.395	0.489	693
Somewhat not	0.053	0.225	693
Not at all	0.081	0.273	693
Don't know	0.004	0.066	693
Impact: Large impact	0.443	0.497	693
Small impact	0.364	0.481	693
No impact	0.049	0.216	693
Don't know	0.144	0.352	693
Timing: Today (already observable)	0.546	0.498	559
In 10 years	0.172	0.377	559
In 30 years	0.186	0.389	559
Don't know	0.097	0.296	559
Feeling: Very worried	0.104	0.306	364
Not very worried	0.747	0.435	364
Don't know	0.148	0.356	364
Manifestation: More drought	0.563	0.496	944
More winter rain	0.341	0.474	944
More storm	0.607	0.489	944
Less frost	0.436	0.496	944

Approximately 73% of the private forest owners are aware of climate change (*Perception*) and most of them think that it is human-induced (*Anthropic*). Most of the respondents are persuaded that climate change will have an impact (either small or large), and they think that the impacts are already observable today (*Timing*). Generally, the respondents are not very worried about climate change impacts for their own forest property. We also questioned them about how climate change reveals itself in their forests and most of them said that climate change increases the frequency and intensity of drought as well as storm events.

Table 3 presents the results in terms of adaptation choices. We can see that 16.1% have already changed their practices (*Change_practices*). Among those who already adapt (*Past*), they mainly changed the way they thin (*Thinning*) and move towards irregular stands (*Irregular*) as adaptation strategies. The triggering of the changes is specialised information in the forestry sector (*Specialised info*). The motivation to adapt is mostly the desire to reduce the damage due to climate change (*Damage reduction*). To better support them in their changes in practices, forest owners indicated that they were interested in specialised training (*Training*) on climate change and its regulations.

The forest owners who do not plan to adapt evoked the following reasons: they think they can still wait (*Can wait*), current regulations limit their means of action (*Admin rules*), lack of money (*Money*) and other priorities regarding forest management (*Other priorities*).

Table 3. Changes in management practices.

Variable	Mean	Std. Dev.	N
Change_practices	0.161	0.368	663
Past (for more than 5 years)	0.073	0.26	703
Past (in the past 5 years)	0.08	0.271	703
Plan (in the next 5 years)	0.181	0.385	703
No plan	0.61	0.488	703
Don't know	0.057	0.232	703
Among which "Past"			
Thinning	0.644	0.481	104
Early harvest	0.467	0.501	105
Late harvest	0.265	0.443	102
Irregular	0.635	0.484	104
Regular	0.5	0.502	106
Triggering: Professional advice	0.141	0.349	191
Friendly advice	0.068	0.253	191
Specialised info	0.529	0.5	191
Renewal_doc	0.262	0.441	191
Motivation: Ecosystem	0.004	0.064	225
Resilience	0.018	0.132	225
Productivity	0.052	0.222	225
Damage reduction	0.161	0.367	225
Support: Financial/tax	0.066	0.249	196
Technical assistance	0.087	0.282	196
Scientific answers	0.24	0.428	196
Training	0.607	0.49	196
No change: Limited info	0.01	0.102	382
Contradicting info	0.026	0.16	382
Can wait	0.34	0.474	382
Other priorities	0.147	0.354	382
Admin rules	0.186	0.39	382
User pressure	0.12	0.326	382
Money	0.17	0.376	382

When looking at effective (*Past*) management practices, heterogeneities by area owned and region are relatively limited, as presented in Tables 4 and 5. However, we will see in the next section that when controlling by individual characteristics, adaptation is much lower in regions with the two largest cities (Paris and Lyon).

Table 4. Adaptation strategies by area class.

	Thinning	Early harvest	Late harvest	Irregular	Regular	N
4 to 10 ha	0.67	0.33	0.50	0.71	0.48	48
10 to 25 ha	0.69	0.41	0.23	0.52	0.33	29
25 to 100 ha	0.49	0.49	0.45	0.50	0.50	118
> 100 ha	0.70	0.68	0.15	0.67	0.56	27

Table 5. Adaptation strategies by region.

	Thinning	Early harvest	Late harvest	Irregular	Regular	N
AUVERGNE - RHONE-ALPES	0.60	0.32	0.26	0.57	0.45	31
BOURGOGNE - FRANCHE-COMTE	0.70	0.55	0.25	0.74	0.30	33
BRETAGNE - PAYS de la LOIRE	0.70	0.35	0.30	0.43	0.60	23
CENTRE -VAL de LOIRE - ILE de F	0.75	0.40	0.36	0.44	0.38	16
CORSE - PACA - OCCITANIE	0.86	0.21	0.38	0.62	0.38	14
GRAND EST	0.61	0.49	0.29	0.76	0.42	37
HAUTS de FRANCE - NORMANDIE	0.65	0.40	0.37	0.55	0.57	37
NOUVELLE-AQUITAINE	0.53	0.50	0.28	0.58	0.68	32

3.2 Statistical analysis

We first present the determinants of the adaptation decision and, second, the determinants associated with each of the five adaptation strategies.

3.2.1 Adaptation vs. non-adaptation: the determinants

Table 6 presents the results of the three regressions conducted. The variable regressed is binary: *Change_practices.* This variable encompasses all the private forest owners who have already adopted adaptation in the past 5 years and for more than 5 years (*Past*). As a consequence, these regressions allow us to compare the determinants of those who have already adopted adaptation *(Past)* and the others *(Plan, No plan, Don't know).*

Model (1) presents regression with a clustering at the department level and Model (2) adds regional fixed effects to the departmental clustering. Finally, Model (3) considers a clustering at the regional level and regional fixed effects. These precisions appear at the end of the table.

We controlled for individual, property and location characteristics. We tested standard individual controls such as age, education level and socio-economic status (socio-professional categories) of the owners, as well as administrative variables (documents provided related to forest management). In addition, we looked at the relationship between reasons for owning woods and the climate change-related beliefs of owners and their propensity to adapt.

The results are almost the same regardless of the model. Since education level and owner's age were not found to be significant drivers in any specifications, they were dropped from the result tables.

Some characteristics of the forester and the forest are significant. Being a woman has a significant and negative effect on the adaptation decision. All of the SPC also have a significant and positive effect compared to the category *Never worked*. Regarding the forest, the area has a significant and positive impact. The fact of having received revenue from logging in the last 12 months always has a negative impact but is significant only for Models (1) and (2), while revenue from hunting is always negative and has a significant impact with respect to *Other objectives*. Some objectives indicated by the forest owners for their forests appeared to always be positive and highly significant: *Biodiversity, Heritage, Leisure* and *Timber*. Being able to provide a management document (*Manag_document*) has a significant and positive impact on the decision. The location of the forest somewhere other than in NOUVELLE-AQUITAINE generally has a significant and negative impact on the adaptation decision. One exception is BOURGOGNE-FRANCHE-COMTE where the impact, although negative, is not significant.

Table 6. The determinants of the change in practices.

	Model (1)	Model (2)	Model (3)
Area	0.00224 *	0.00211*	0.00208*
	(0.00117)	(0.00116)	(0.00109)
Revenue_12 months	-0.0521	-0.0401	-0.0367
	(0.288)	(0.290)	(0.415)
Gender	-1.407**	-1.026**	-1.020**
	(0.427)	(0.440)	(0.473)
Farmer	4.229***	4.148***	4.144***
	(0.253)	(0.281)	(0.240)
Artisan	3.660***	3.629***	3.624***
	(0.296)	(0.327)	(0.293)
Superior	4.259***	4.209***	4.203***
	(0.255)	(0.285)	(0.253)
Intermediary	4.239***	4.160***	4.155***
	(0.270)	(0.309)	(0.281)
Employee	3.929***	3.868***	3.840***
	(0.404)	(0.408)	(0.362)
Worker	4.831***	4.750***	4.745***
	(0.366)	(0.385)	(0.241)
Manag_document	0.436**	0.450**	0.453**
	(0.171)	(0.185)	(0.200)
Revenue_logging	-0.565**	-0.530*	-0.529
	(0.267)	(0.272)	(0.361)
Revenue_hunting	-0.327*	-0.379*	-0.377*
	(0.195)	(0.211)	(0.180)
Obj_Biodiversity	3.718***	3.909***	3.917***
	(0.394)	(0.486)	(0.384)
Obj_Heritage	4.067***	4.099***	4.107***
	(0.694)	(0.823)	(0.863)
Obj_Leisure	4.029***	4.209***	4.216***
	(0.377)	(0.487)	(0.441)
Obj_Timber	3.821***	4.006***	4.014***
	(0.543)	(0.626)	(0.742)
Impact[4]	0.292	0.336*	0.334*
	(0.188)	(0.196)	(0.168)
More_drought	0.281*	0.271	0.269
	(0.170)	(0.179)	(0.201)

[4] Impact has been coded as follows: Impact = 1 for "Large impact" and "Small impact"; Impact = 0 for "No impact" and "Don't know".

Less_frost	-0.128	-0.175	-0.17**
	(0.126)	(0.129)	(0.0816)
More_winter_rain	-0.133	-0.152	-0.150*
	(0.143)	(0.138)	(0.0849)
Perception_Yes	0.398***	0.420***	0.418***
	(0.129)	(0.135)	(0.165)
Anthropic[5]	-0.264	-0.318*	-0.319***
	(0.174)	(0.175)	(0.123)
AUVERGNE-RHONE-ALPES		-0.685**	-0.686***
		(0.272)	(0.0487)
BOURGOGNE - FRANCHE-COMTE		-0.0379	0.0404
		(0.210)	(0.0351)
BRETAGNE - PAYS de la LOIRE		-0.481	0.484***
		(0.300)	(0.0915)
CENTRE -VAL de LOIRE - ILE de F		-0.871***	-0.872***
		(0.330)	(0.0832)
CORSE - PACA - OCCITANIE		-0.321	-0.332***
		(0.261)	(0.0516)
GRAND EST		-0.251	-0.254***
		(0.304)	(0.0820)
HAUTS de FRANCE - NORMANDIE		-0.164	-0.167***
		(0.264)	(0.0628)
Constant	-8.296*** (0.978)	-8.044***	-8.049***
		(1.039)	(0.586)
Observations	628	628	629
Department-level clustering	Yes	Yes	No
Regional-level clustering	No	No	Yes
Adjusted R²	0.1836	0.2101	0.2101

Standard errors in parentheses; $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Concerning the variables related to climate change, we observed that replying "Yes" to the question "Do you think the climate is changing?" (*Perception_Yes*) has a significant and positive impact on the adaptation decision. We can observe that respondents who think that climate change will have an impact (*Impact*) have a higher chance to adapt their management. Regarding the way climate change manifests itself among the respondents indicates less clear results: *More_drought* is significant only for Model (1), while *Less_frost* and *More_winter_rain* are significant for Model (3). Finally, people who consider that climate change has an anthropic origin *(Anthropic*) have a lower chance to adapt than the others, and it is significant for Models (2) and (3).

Respondents who had not changed their practices and did not wish to do so in the next five years (N = 429) were asked about the reasons for this refusal. Theses reasons are presented in Table 7.

Table 7. Reasons for "no adaptation".

Variable	Mean	Std. Dev.	Min.	Max.	N
Reasons for not adapting					
Not enough information	0.14	0.347	0	1	429
Contradictory information	0.133	0.34	0	1	429
Prefer to wait	0.321	0.467	0	1	429
Other priorities	0.105	0.307	0	1	429
Money	0.111	0.314	0	1	429
Administrative rules	0.094	0.292	0	1	429
User pressure	0.048	0.214	0	1	429
Incentives to change					
Climate change assessment	0.114	0.318	0	1	429
Need insurance	0.042	0.2	0	1	429
Sanitary assessment	0.111	0.314	0	1	429
Experimental plot (impact evaluation) tests	0.108	0.311	0	1	429
Money	0.143	0.35	0	1	429

5 Anthropic has been coded as follows: Anthropic = 1 for "Yes" and "Somewhat yes"; Anthropic = 0 for "Somewhat not", "Not at all" and "Don't know".

The answer "Prefer to wait" was the most frequently given. The notion of information is also very important - it is cited by many respondents as either absent or contradictory. For those respondents who do not plan to change their practices, would certain aids or accompaniment encourage them to do so? Approximately 50% of the owners who do not wish to change their practices in the next 5 years are not interested (and/or do not know) in the proposals we have made to them. This may mean that our proposals were not varied enough or that these owners do not identify with the policies promoted by the forest and wood industry.

3.2.2 Drivers of the adaptation strategies

We first present bilateral correlations between the five adaptation strategies in Table 8. We observe that the correlations between strategies are low except in two cases that present negative correlation coefficients: between *Late harvest* and *Early harvest*, and between *Regular* and *Irregular*. This result seems obvious since the two strategies are the opposite of each other each time and, consequently, it is impossible to apply them at the same time on the same stand.

Table 8. Bilateral correlations between the adaptation strategies.

	Thinning	Early harvest	Late harvest	Irregular	Regular
Thinning	1.0000				
Early harvest	0.0753	1.0000			
Late harvest	0.0948	-0.2512	1.0000		
Irregular	0.1465	0.0759	0.0518	1.0000	
Regular	-0.0171	0.0513	0.0942	-0.3770	1.0000

Table 9 presents the regressions per adaptation strategy with regional fixed effects and clustering at the regional level (corresponding to Model (3) in Table 6).

Several observations can be made on the basis of Table 9. First, a quick look at the table shows that none of the variables has a significant impact on the five strategies. Second, we identify several relevant drivers for *Early harvest* and *Late harvest*, while it is more difficult to identify some for *Thinning*, *Regular and Irregular*. A third interesting (and reassuring) result is that we have opposite significant impacts of variables for *Early harvest* and *Late harvest*, and for *Irregular* and *Regular*. They are different adaptation strategies that are opposed in terms of management and, consequently, it seems obvious that the impact should be opposite as well. For example, thinking that the impact of climate change will be small encourages people to adopt *Late harvest* and discourages them from adopting *Early harvest*. In the same way, thinking that climate change is not human-induced has a significant and positive effect on *Irregular* and a significant and negative one on *Regular*.

Table 9. Drivers by strategy, inter-regional clusters and regional fixed effects.

	Thinning	**Early harvest**	**Late harvest**	**Irregular**	**Regular**
Area	0.000650	0.00213	-0.00192	-.000272	0.00146
	(0.00107)	(0.00167)	(0.00230)	(0.00124)	(0.00167)
Revenue_12 months	-1.380*	0.0316	0.657	0.0327	-0.570
	(0.719)	(0.590)	(0.748)	(0.782)	(0.743)
Farmer	-0.459	0.709	-1.085*	-0.0152	0.133
	(0.548)	(0.604)	(0.577)	(0.506)	(0.438)
Artisan	-0.666	1.322*	0	0.0940	0.326
	(0.768)	(0.777)	(.)	(0.797)	(0.657)

Superior	-0.250	0.588	-1.292**	-0.263	0.256
	(0.522)	(0.572)	(0.554)	(0.498)	(0.467)
Intermediary	-0.101	1.359*	-1.402**	-0.398	0.694
	(0.611)	(0.697)	(0.612)	(0.706)	(0.546)
Employee	-2.003***	0.465	-0.634	-0.219	0.728
	(0.647)	(0.690)	(0.667)	(0.836)	(0.974)
Manag_document	0.238	1.117***	-0.109	0.962***	0.361
	(0.367)	(0.410)	(0.423)	(0.340)	(0.330)
Revenue_logging	-0.959	0.242	1.244*	0.128	-0.539
	(0.650)	(0.547)	(0.637)	(0.739)	(0.668)
Revenue_hunting	-0.122	-0.0438	-0.698*	0.188	0.0910
	(0.308)	(0.362)	(0.374)	(0.321)	(0.330)
Obj_Biodiversity	1.201	1.537*	-1.115	0.106	-1.473*
	(0.837)	(0.870)	(0.899)	(0.506)	(0.830)
Obj_Leisure	1.417*	1.436*	-0.764	0	-0.410
	(0.753)	(0.775)	(0.795)	(.)	(0.789)
Impact	-0.291	-0.615	0.315	0.612	-0.0373
	(0.535)	(0.633)	(0.401)	(0.413)	(.479)
More drought	-0.455	-0.510	0.116	0.0478	0.0619
	(0.466)	(0.412)	(0.451)	(0.388)	(0.423)
Less frost	0.362	-0.492*	0.225	0.346	-0.222
	(0.307)	(0.264)	(0.348)	(0.273)	(0.280)
More winter rain	0.102	-0.240	0.207	0.393	-0.0306
	(0.258)	(0.312)	(0.330)	(0.259)	(-0.226)
Perception Yes	-0.127	-0.130	-0.258	-0.103	-0.211
	(0.255)	(0.310)	(0.364)	(0.362)	(0.286)
Anthropic	-0.769*	0.481	1.145*	-0.430	0.304
	(0.447)	(0.434)	(0.600)	(0.441)	(0.401)
Constant	2.933	-2.381	-1.116	-1.127	0.855
	(2.021)	(1.664)	(2.222)	(1.751)	(1.741)
Observations	97	98	88	93	99
Adjusted R^2	0.1333	0.3029	0.2899	0.1978	0.2228

Standard errors in parentheses; *p < 0.1; **p < 0.05; ***p < 0.01

Table 9 shows in greater detail that having collected revenue from the forest over the last 12 months significantly and negatively impacts the *Thinning* strategy.

The impact of the SPC is less clear. The SPC has no significant impact on *Irregular* and *Regular* and sometimes has significant impacts on the three other strategies. For example, being a *Farmer* has a significant and negative impact on *Late harvest*, whereas being an *Employee* has a significant and negative effect on *Thinning,* etc.

Having a forest management document acts like a high incentive to adopt *Early harvest* and *Regular* as adaptation strategies.

Having collected revenue in the last 12 months from logging and hunting (compared to other sources) has a significant effect on *Late harvest*. This effect is positive when revenue comes from logging and negative when it comes from hunting.

Owning a forest mainly for biodiversity conservation (*Obj_Biodiversity*) and leisure-related reasons (*Obj_Leisure*) has a significant and positive impact on *Early Harvest*.

Respondents who consider that the impact of climate change will be real (either *Large* or *Small*) are discouraged to adopt *Early harvest*, while those who think that climate change will have no impact are encouraged to postpone the harvest (*Late harvest*).

Being sure that the origin of climate change is anthropic has a significant and negative effect on *Thinning,* whereas it has a significant and positive one on *Late Harvest*.

4. Discussion

In a context where countries are engaged in international negotiations to limit the impact of climate change, forests have a main role to play and it may be in the interest of governments to encourage forest owners to adapt (at least to maintain or, at best, to increase forest cover and, consequently, carbon stocks). Our article provides insights into the way government may encourage owners to adapt as well as into potential vectors that may be used for public support.

The intuition that the determinants of the adaptation decision are strategy-dependent turns out to be true since none of the variables has the same significant impact on the five adaptation strategies considered. This means that talking about adaptation in general may make no sense and that the incentives and design of public policies should probably be conducted at the scale of the adaptation strategy itself. One can thus imagine encouraging strategies that favour both adaptation and mitigation. This complementarity is not always possible and trade-offs may be necessary.

In line with that observation, we identify a large number of significant drivers for the adaptation strategies based on harvest management (*Early harvest* or *Late harvest*). Advancing or delaying the final harvest has been a classical risk management strategy in forestry for a long time now and it is easy to implement throughout the rotation process. Moreover, this strategy offers flexibility compared to the other ones like *Irregular* or *Regular*. This result is in line with Brunette et al. (2020) who observed that forestry professionals are afraid of changing routines and that current forest management practices are characterised by inertia.

In order to eliminate this inertia, the improvement and clarification of the information available to owners concerning climate change and its impact on forest management is an issue. Moreover, knowing that the climate is changing is not sufficient to initiate an adaptation process. Indeed, private forest owners have to be convinced that the impacts of climate change will be real, either small or large, to make the decision to adapt. This result confirms anecdotal evidence based on descriptive statistics that show that private forest owners are in need of specialised information in the forestry sector as well as training on climate change and its regulations. This result is also in line with Yousefpour and Hanewinkel (2015) who show that "*forest decision-makers must be aware of the nature and implications of climate change in order to develop management strategies that may help to reduce adverse effects and sustain productive forests*".

An interesting vector that may be used for public policy is the management documents. Indeed, our results reveal that having a forest management document increases the forest owner's propensity to adapt to climate change. Although we cannot discuss the channels behind those relationships as they are beyond the scope of this paper, it seems that owners who were able to provide a document to certify their forest management (half of the people in the sample were able to provide either a simple or more detailed forest management plan or at least a list of good practices) are more inclined to adapt their management practices.

Finally, when looking at the propensity of specific owners to adapt to climate change per region, we observed a higher propensity in NOUVELLE-AQUITAINE (where pines are grown intensively for paper pulp production and related products) and in BOURGOGNE-FRANCHE-COMTE. Alternatively, CENTRE-VAL-DE-LOIRE-Ile de FRANCE (the region encompassing Paris, the capitol) and AUVERGNE-RHONE-ALPES (the region with the second biggest city in France: Lyon) seem to be the two regions with the lowest propensity to adapt. This regional heterogeneity shows that our results should be interpreted with caution (also, because we do not have owner fixed effects that would make it possible to more robustly control for individual and especially unobservable, specific characteristics). This is also in line with Spathef et al. (2014) who said that it is "*of utmost importance to implement regionally-based adaptation measures that are accepted by the stakeholders involved*".

5. Conclusion

This paper focuses on the determinants of the French forest owner's adaptation decisions. We show that the characteristics of the forest (area, management document, location, objective) and of the forest owners (gender, SPC, source of revenue), as well as the variables linked to climate change (perception, impact, origin), may explain the decision to adapt or not. From a more original perspective, we look at the determinants according to adaptation strategy. We found that the determinants are strategy-dependent, thus allowing us to identify levers to encourage forest owners to adapt.

Some of the limits of this study can be identified. The literature has already shown that the forest owner's attitude towards risk is a driver for many decisions that imply risk, such as harvesting (Brunette et al. 2017), insurance (Sauter et al. 2016) and adaptation decision (Brunette et al. 2020). However, in this study we do not have this variable as a potential characteristic of the forest owner. This article focuses on five adaptation strategies, whereas other ones are widely recommended to forest owners, such as reduction of density, better-adapted tree species, species mix, etc.

Acknowledgments

The MACCLIF project was carried out within the framework of the actions of the RMT AFORCE (www.reseau-aforce.fr) thanks to the financial support of the French Ministry of Agriculture and the France Bois Forêt joint trade organisation. It has also benefited from government funding overseen by the French National Research Agency (ANR) under the programme, Investissements d'Avenir (Investments for the Future), reference no. ANR-11-LABX-0002-01 (Laboratoire d' Excellence TREE). The questionnaire and its results presented here were carried out together with the private foresters observation network of the National Centre for Private Forest Owners (CNPF) and financed by France Bois Forêt. The UMR BETA is supported by a grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" programme (ANR-11-LABX-0002-01, Laboratoire d' Excellence ARBRE).

References

Andersson E, Keskitalo ECH, Lawrence A (2017) Adaptation to climate change in forestry: A perspective on forest ownership and adaptation responses. Forests 8(12):493-512.

Andersson E, Keskitalo ECH (2018) Adaptation to climate change? Why business-as-usual remains the logical choice in Swedish forestry. Global Environmental Change 48:76-85.

Bergh J, Freeman M, Sigurdsson B, Kellomäki S, Laitinen K, Niinistö S, Peltola H, Linder S (2003) Modelling the short-term effects of climate change on the productivity of selected tree species in Nordic countries. Forest Ecology and Management 183:327-340.

Blennow K, Persson J, Tomé M, Hanewinkel M (2012) Climate Change: Believing and Seeing Implies Adapting. PLoS ONE 7(11): e50182.

Bolte A, Ammer C, Löf M, Madsen P, Nabuurs G-J, Schall P, Spathelf P, Rock J (2009) Adaptive forest management in central Europe: climate change impacts, strategies and integrative concept. Scandinavian Journal of Forest Research 24:473-482.

Bréda N, Brunette M (2019) Are 40 years better than 55? An analysis of the reduction of forest rotation to face drought event in a Douglas fir stand. Annals of Forest Science 76:29.

Brèteau-Amores S, Brunette M, Davi H (2019) An economic comparison of adaptation strategies towards a drought-induced risk of forest decline. Ecological Economics 164:106294.

Brunette M, Hanewinkel M, Yousefpour R (2020) Risk aversion hinders forestry professionals to adapt to climate change. Climatic Change 162:2157–2180.

Brunette M, Foncel J, Kéré E (2017) Attitude towards Risk and Production decision: An Empirical analysis on French private forest owners. Environmental Modeling and Assessment 22(6):563-576.

Brunette M, Costa S, Lecocq F (2014) Economics of species change subject to risk of climate change and increasing information: a (quasi-) option value analysis. Annals of Forest Science 71(2):279-290.

Flannigan MD, Stocks BJ, Wotton BM (2000) Climate change and forest fires. Science of the Total Environment 262:221-229.

Fuhrer J, Beniston M, Fischlin A, Frei C, Goyette S, Jasper K, Pfister C (2006) Climate risks and their impact on agriculture and forests in Switzerland. Climatic Change 79:79-102.

Hochrainer-Stigler S, Mechler R, Pflug G, Williges K (2014) Funding public adaptation to climate-related disasters estimates for a global fund. Global Environmental Change 25:87-96.

IGN, Institut National de l'Information Géograhique et Forestière (2016) La surface forestière. https://inventaire-forestier.ign.fr/spip.php?rubrique11 (webpage consulted on January 11th, 2021).

Jönsson AM, Lagergren F, Smith B (2015) Forest management facing climate change - an ecosystem model analysis of adaptation strategies. Mitigation and Adaptation Strategies for Global Change 20:201-220.

Jump AS, Hunt JM, Peñuelas J (2006) Rapid climate change-related growth decline at the southern range edge of Fagus sylvatica. Global Change Biology 12:2163-2174.

Ogden AE, Innes JL (2009) Application of structured decision making to an assessment of climate change vulnerabilities and adaptation options for sustainable forest management. Ecology and Society 14(1):11.

Sauter P, Möllmann TB, Anastassiadis F, Musshoff O, Möhring B (2016) To insure or not to insure? Analysis of foresters' willingness-to-pay for fire and storm insurance. Forest Policy and Economics 73:78-89.

Schelhaas MJ, Nabuurs G, Schuck A (2003) Natural disturbances in the European forests in the 19th and 20th centuries. Global Change Biology 9:1620-1633.

Schou E, Jacobsen JB, Kristensen KL (2012) An economic evaluation of strategies for transforming even-aged into near-natural forestry in a conifer-dominated forest in Denmark. Forest Policy and Economics 20:89-98.

Seidl R, Schelhaas MJ, Lexer MJ (2011) Unraveling the drivers of intensifying forest disturbance regimes in Europe. Global Change Biology 17:2842-2852.

Seidl R, Schelhaas MJ, Rammer W, Verkerk PJ (2014) Increasing forest disturbances in Europe and their impact on carbon storage. Nature Climate Change 4:806-810.

Sousa-Silva R, Ponette Q, Verheyen K, Van Herzele A, Muys B (2016) Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium. Forest Ecosystems 3:22.

Sousa-Silva R, Verbist B, Lomba A, Valent P, Suškevičs M, Picard O, Hoogstra-Klein MA, Cosofret VC, Bouriaud L, Ponette Q, Verheyen K, Muys B (2018) Adapting forest management to climate change in Europe: Linking perceptions to adaptive responses. Forest Policy and Economics 90:22-30.

Spathelf P, van der Maaten E, van der Maaten-Theunissen M, Campioli M, Dobrowolska D (2014) Climate change impacts in European forests: the expert views of local observers. Annals of Forest Science 71(2):131-137.

Spittlehouse D, Stewart R (2003) Adaptation to climate change in forest management. BC Journal of Ecosystems Management 4:1-11.

Van Aalst MK (2006) The impacts of climate change on the risk of natural disasters. Disasters 30:5-18.

VEM, Veille Economique Mutualisée (2017) Chiffres clés et études. https://vem-fb.fr/index.php/chiffres-cles/valeur-ajoutee-et-emploi (webpage consulted on January 11th, 2021).

Yousefpour R, Hanewinkel M (2015) Forestry professionals' perceptions of climate change, impacts and adaptation strategies for forests in South-West Germany. Climatic Change 130:273-286.