Sousa-Silva et al. Forest Ecosystems (2016) 3:22
DOI 10.1186/s40663-016-0082-7

Forest Ecosystems

RESEARCH Open Access

Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium

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Abstract

Background: Climate change is likely to cause significant modifications in forests. Rising to this challenge may require adaptation of forest management, and therefore should trigger proactive measures by forest managers, but it is unclear to what extent this is already happening.

Methods: The survey carried out in this research assesses how forest stakeholders in Belgium 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.

Results: Respondents indicated strong awareness of the changing climate, with more than two-thirds (71 %) expressing concern about the impacts of climate change on their forests. However, less than one-third of the respondents (32 %) reported modifying their management practices motivated by climate change. Among the major constraints limiting their climate related actions, lack of information was considered the most important for managers of both public and private forests.

Conclusions: Knowledge transfer is an essential condition for research to lead to innovation. Improving the communication and demonstration of possible solutions for climate change adaptation is therefore likely to be the most effective strategy for increasing their adoption.

Keywords: Adaptation, Adoption, Belief, Stakeholders, Internet survey, Logistic regression

Background

Climate change is one of the world's greatest challenges. Despite a number of uncertainties, scientific evidence has led to a general consensus that climate change is occurring and is profoundly influenced by human activity. According to the Intergovernmental Panel on Climate Change (IPCC) fifth assessment report 'it is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century' (IPCC 2013a, p.17). However, even recent extreme weather events have been insufficient to deliver the required change in public and political action. On the contrary, in recent years a decline in public concern and acceptance of climate change has been documented (Capstick and Pidgeon 2014). The greatest barrier to public recognition of human-made climate change is possibly caused by natural local climate variability (Hansen et al. 2012). Given that climate change cannot be directly experienced or straightforwardly observed, it is difficult for individuals to link local weather events and climate change. Yet, although climate fluctuations are cyclical, rapid global warming in the past decades is highly unusual (Hansen et al. 2012).

Projections of climate change effects for forests and forest sector are as follows: increased frequency and intensity of tree diseases and pest outbreaks due to a warmer climate, and particularly warmer winters, which increases the survival of parasites (Dale et al. 2001); a modification of the potential distribution ranges of tree species, as conditions are shifting far faster than their ability to adapt in place or migrate to more suitable locations (Bell and Collins 2008); and warmer growing

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seasons and rising CO_2 concentrations, which, in the short term, will enhance forest production where soil nutrient and water availability allow. However, under nutrient-poor or water-deficient conditions, such as those in the Belgian forest regions of Ardennes and Campine, respectively (Campioli et al. 2011), this would not apply. As a result, there is a dire need to raise awareness of climate-related risks (and opportunities) among forest stakeholders, and engage them in adaptation.

The IPCC (2013b) defines adaptation as an 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'. Actions of climate change adaptation in forestry will have to be taken at different hierarchical levels of decision making, but ultimately the key actors on the field will be the forest owners and managers (CPF 2008). In Belgium, more than half of the forests are privately owned, often divided into parcels as small as 1 ha (2.5 acres) (Ouden et al. 2010; van Gameren and Zaccai 2015), but whose management is undertaken, in general, by a hired manager or by a cooperative selected by the owners. These stakeholders, defined as people (whether owners or managers) who directly participate in forest management decisions (Locatelli et al. 2010), are particularly sensitive to climate change impacts since the forestry sector is exposed to and directly dependent on climate (Blennow and Persson 2009), and therefore, insight into their perceptions of climate change risk is crucial. Perceptions are, in this context, defined as the awareness of the occurrence of climate change and the sensitivity to its adverse effects (Clayton et al. 2009).

Existing research suggests that perspectives on climate change are influenced by ethical, social, and political values and attitudes, but also by perceived personal experiences (Blennow et al. 2012; Myers et al. 2012). Indeed, people's strength of belief in local effects of climate change has been shown to be strongly correlated with their willingness to undertake adaptive practices (Blennow et al. 2012; Lenart and Jones 2014). Moreover, from a social point of view, climate change belief is an extremely important construct to understand people's attitudes and actions (Goldman 1999). In this sense, belief is defined as a personal conviction that is not necessarily supported by science-based evidence - but that is shaped by the overall context in which they occur, including the scientific understanding we have of it.

Several studies have investigated the perceptions of forest sector stakeholders on climate change and the implications for forest management (see for example Blennow et al. 2012; Yousefpour and Hanewinkel 2015; Nelson et al. 2016; Seidl et al. 2016), using different questions, approaches, and sample sizes, demonstrating a wide general awareness of the issue. In this context, identifying the perceptions of stakeholders can inform us as to their level of knowledge of and degree of concern for climate change impacts, their understanding of risk and vulnerability, and whether they are willing to engage in the adaptation process. Thus, in our study, we attempted to reach this objective through a comprehensive survey involving various forest stakeholders, including forest owners and managers, both public and private.

The research presented here focuses on the perceptions of the vulnerability of forests to climate change and the impediments that limit the ability of forest owners and managers to prepare and respond to climate change. Our specific objectives were to understand (i) if individuals who have direct experience of extreme weather, which they attribute to climate change, are more concerned by and engaged with the issue than those who have not experienced it, (ii) whether they have made changes to their management based on the impacts that climate change may have on forests, and (iii) what are the main constraints to implementing these actions. This approach is in line with the methodology in Blennow et al. (2012) and FAO (2012) who used mailed questionnaires to elicit the perceptions of forest owners and forest managers to prepare and respond to climate change. We thus also test the hypothesis proposed by Blennow et al. (2012) that measurements of belief in local effects of climate change and in having experienced climate change are sufficient for accurately explaining adaptation.

Methods

Case study

Belgium is a strongly urbanized country, with a territory of 30,528 km^2. Forests cover roughly 22 % of the land area, with near to one third protected as part of the Natura 2000 network. The large majority of the forests (79 %) is in the southern Walloon (French speaking) region, whereas the northern Flemish (Dutch speaking) region has a much smaller forest cover. In Wallonia, 50 % of forest is publicly owned, while almost 70 % of the forest area of Flanders is privately owned (Ouden et al. 2010; van Gameren and Zaccai 2015). Most private forest owners hold very small properties. Traditionally oriented to timber production, over the last 50 years, the management of forests has become more multifunctional (Rondeux 2007; Vandekerkhove 2013).

Research design

The survey was designed to gather evidence from forest stakeholders on the impacts of climate change on their forests and their management. The questionnaire was formulated on the basis of a review of previous studies on perceptions on climate change (Blennow and Persson 2009; Blennow et al. 2012; FAO 2012) and recommended adaptation actions (Lindner et al. 2008; FAO

2013). It was formulated in English, translated into French and Dutch and pilot tested on a sample of ten individuals in March 2015. Following this review, minor revisions were made, and the survey was made available online between April and July 2015. The survey was disseminated by email, newsletters and online media through forest owners' associations and organisations active in the forest sector in Belgium. Finally, survey respondents were encouraged to forward the advertisement to colleagues, creating a snowball effect (Goodman 1961).

There were a total of 29 questions with dichotomous and multiple-choice answers. The former asked whether the respondents believed in climate change, their experience of the impacts and whether they had made changes to their management. The latter was used for the remaining questions. Risk perception and level of concern were measured on a five-point scale, ranging from 'definitely no' to 'definitely yes'. The questionnaire was divided into five sections, the first of which collected personal information, such as their socio-demographic and forest-related characteristics. Respondents were requested to indicate to which stakeholder group they belonged, owners or managers, and their role in the management of respective forests. Private owners were divided into two categories, depending on whether they manage their own forest (active owners) or not (passive owners). Managers, either in the public sector or private sector, can be understood as the people who assist the forest owner to adapt to climate change or who need to make decisions about whether, how and when to adapt on the owner's behalf. Public administration included Flemish (ANB; 'Agentschap voor Natuur en Bos') and Walloon (DNF; 'Département de la Nature et des Forêts') forest administration and other regional or local authorities. Private managers included non-governmental forestry/nature associations, private forest management organizations and forestry/timber professionals who do not own forest land. The second section asked whether respondents believed in climate change and whether climate change impacts on forests would affect their management. The following section sought to ascertain whether respondents had observed any evidence of climate change on their forests and if so, what was the nature of the impacts. Respondents were also asked about their level of concern about climate change impacts on their forests and the extent to which these risks are considered serious threats to their forests. Questions in the next section focused on assessing whether respondents had made changes to their management practices based on changing climate. Here respondents were presented a list of 17 potential measures to adapt to climate change (Lindner et al. 2008) and they were asked to choose all those that they had carried out in their forests. Respondents were also asked about the main constraints to implementing adaptation actions. Those who indicated not having adapted were assumed to not have taken concrete actions to change their management practices, whereas respondents who reported having made changes in their management were assumed to not have significant hindrances that would prevent them to undertake adaptation actions. Lastly, respondents were asked about their sources of information on climate change.

An online survey was used because of the speed of data collection, anonymity and ability to reach a large and diverse population at low cost (Reips 2002a). The survey is easily accessible and participation is more voluntary compared to surveys by telephone or door-to-door (Roth 2006; Dewaelheyns et al. 2013). A drawback of online surveys lies in the potential lack of representativeness (Evans and Mathur 2005), excluding from the survey those who do not have access to and ability to use the Internet. Nevertheless, within the forest sector in Belgium, it has become common practice for associations to communicate with their members through e.g. newsletters, who are therefore used to this type of interaction. Furthermore, although the representativeness of the sample obtained could not be verified, since reference data on the ownership of private forests in Belgium do not exist, our study compared favourably with other published findings (e.g. Blennow et al. 2012; Valente et al. 2015; van Gameren and Zaccai 2015; Seidl et al. 2016). To reduce the problem of dropout, all participants were offered a chance for a small financial reward (Reips 2002a, b).

Data analysis

After we collected the data, descriptive statistics were used to summarize the characteristics of the respondents (Table 1), and a Pearson's Chi-squared test was applied to examine the relationships among forest owners and forest managers (Table 2). Finally, multiple logistic regression was used to explore how beliefs and experiences affect the intention of forest owners and managers to adapt to climate change. Responses to each question were entered either as ranked or binary dependent variables and the stated adaptation of forest management as independent variable. The best and most parsimonious model was chosen by means of a stepwise approach using Akaike's Information Criterion (AIC) as a measure of relative goodness of fit, where smaller values represent better fits, and variables remained in the final model if the associated P value was < 0.05. Tjur's coefficient of discrimination (D) was used to evaluate and compare the different models, since it is closely related to linear measures of fit and is not based on the likelihood function (Tjur 2009). Regression

Table 1 Characteristics of respondents and samples of forest owners and forest managers

	All respondents	Forest owners	Forest managers
Gender			
Male	88 %	87 %	90 %
Female	12 %	13 %	10 %
Age			
< 30 years	9 %	5 %	14 %
30–39 years	14 %	9 %	21 %
40–49 years	20 %	17 %	23 %
> 50 years	57 %	70 %	42 %
Forest location			
Flanders	55 %	58 %	51 %
Wallonia	40 %	37 %	43 %
Flanders & Wallonia	3 %	3 %	4 %
Abroad	2 %	3 %	2 %
Education			
Basic education	1 %	1 %	0 %
Secondary education	21 %	19 %	23 %
Higher education	79 %	80 %	77 %
Income			
Average gross annual revenue		<500 €	-
Type of management			
Active/Passive		91 %/9 %	-
Public/Private		-	54 %/46 %
Forest size			
< 2 ha	22 %	32 %	9 %
2–199 ha	43 %	59 %	23 %
> 200 ha	35 %	10 %	68 %
Member of a forest owners' association			
Yes	52 %	61 %	40 %
No	48 %	39 %	60 %
No. of observations	391	220	171

coefficients, standard errors, and significance levels are reported for the full model (Table 3).

Regression analyses were performed using the *brglm* package (Kosmidis 2013), which addresses issues of near perfect separation in logistic regressions (i.e., when there is perfect correspondence of the response variable for most values of the predictors, but not for all) (Heinze and Schemper 2002). All statistical analyses were performed in R (R Development Core Team 2015).

Results

A total of 512 people opened the survey link, of whom 391 (76 %) completed the survey before it was closed. Most participants were male (88 %) and in the over 50-year-old category (57 %), with approximately 80 % having at least a higher education degree (Table 1). Responses were grouped according to the surveyed respondents groups, i.e., forest owners (both active and passive) and managers (both public and private) (Table 2). The majority of respondents are private owners (56 %), 91 % of them being actively involved in forest management. Amongst managers, representation is fairly evenly divided between the public (93) and private (78) sectors.

Climate change and adaptation

Belief

Almost all the respondents (95 %) believe that climate change is already happening and will continue in the future. The degree of belief in climate change did not differ between private forest owners and public or private forest managers. There was also a consensus among forest owners and forest managers that they are worried about climate change. Even 46 % of those surveyed reported being 'very worried' or 'extremely worried' about it.

Regarding the susceptibility to the risk of climate change of their forests, 71 % of all respondents believe that climate change will 'probably' or 'definitely' affect their forests. A perception is mutually shared between public and private managers (71 % vs 67 %). In terms of expected impacts, we found that extreme events were the most commonly cited, followed by forest pests and diseases, with the former being indicated by 72 % of those respondents who expect to be impacted by climate change ($N = 358$). Species changes are also generally anticipated (Fig. 1).

Experience

Half of the respondents stated that they had already experienced climate change (or phenomena that may be linked to climate change). The most commonly mentioned climate change related experiences were strong winds and storms, drought, and extreme precipitation, followed by heat waves (Fig. 2). Out of the respondents who said to not believe in climate change, only one reported having had experience of climate change. The proportion of forest owners who reported experiencing local effects of climate change was similar to the forest managers sample, but lower than among private managers ($p < 0.01$; Table 2).

Forest owners were divided into two categories, depending on whether they manage their own forest (active owners) or not (passive owners). Forest managers, who do not own forest land, were either categorized as being in the public administration (public managers) or in the private sector (private managers). Revenue represents their self-reported total income received annually, before

Table 2 Descriptive statistics of respondents and samples of forest owners and forest managers (in %)

All respon-dents		Owners (O)		Managers (M)				
		Active (O1)	Passive (O2)	Public (M1)	Private (M2)	*P* values H_0: O = M	*P* values H_0: O1 = O2	*P* values H_0: M1 = M2
Belief:	*Do you think that climate change is happening?*							
Yes	95	94		98		0.101	1[a]	0.337[a]
		93.5	95	99	96			
No	5	6		2				
		6.5	5	1	4			
Experience:	*Have you experienced any extreme weather conditions that you interpreted as caused by climate change?*							
Yes	50	41		59		<0.001	0.201	0.008
		42.5	25	49	71			
No	50	59		41				
		57.5	75	51	29			
Adaptation:	*Have you adapted your forest management in response to climate change?*							
Yes	32	27		37		0.042	0.037	0.137
		29.5	5	43	31			
No	68	73		63				
		70.5	95	57	69			
No. of observations	391	200	20	93	78			

[a]Pearson's Chi-squared test with simulated *p*-value (based on 10,000 replicates) by Monte Carlo test

taking taxes or deductions into account, from the forests they own (considered together). Percentages may not total 100 % due to rounding.

Forest owners were divided into two categories, depending on whether they manage their own forest (active owners) or not (passive owners). Forest managers, who do not own forest land, were either categorized as being in the public administration (public managers) or in the private sector (private managers). When asked whether they had undertaken climate change adaptation actions, respondents who answered 'do not know' were grouped together with those who answered 'no'.

Table 3 Parameter estimates and associated statistics of a model for predicting adaptation based on beliefs and constraints associated with adapting forest management to climate change by forest owners and managers

Variable	Estimate (SE)	*z*-stat	*P* value
Intercept	−0.964 (0.449)	−2.148	0.03
belief mgmt adapt	2.079 (0.481)	4.325	<0.001
lack of knowledge	−5.069 (1.635)	−3.101	0.002
lack of finances	−3.632 (1.555)	−2.336	0.02
lack of conviction	−4.239 (1.503)	−2.821	0.005
lack of information	−5.037 (1.669)	−3.019	0.003
lack of capacity	−3.594 (1.540)	−2.334	0.02
increased tree growth	2.653 (0.780)	3.400	<0.001
dnk belief climate change	−5.376 (2.053)	−2.619	0.01
dnk how adapt	−1.831 (0.731)	−2.505	0.01

belief mgmt adapt: belief in the need to adjust forest management practices; dnk belief climate change: do not know whether climate change is happening: dnk how adapt, do not know how to adapt forest management. All diagnostic statistics given for the logistic regression model are significant at $\alpha = 0.05$. The null deviance = 460.49, the degrees of freedom for the null model = 390, the residual deviance = 175.71, and the residual degrees of freedom = 381. The model fits the data significantly better than the null model ($p < 0.0001$)

Adaptation in forest management

Adaptation

Respondents were then asked if they had taken measures to adapt the management of their forest to climate change. More than half of the respondents answered negatively. Respondents who answered 'do not know' (11 %) were grouped together with those who answered 'no' (57 %) for further analysis, as only those who answered affirmatively were considered having consciously changed their management plans or practices as a result of climate change. Managers of public forests have the highest rate of having adapted their management practices although still lower than 50 %. By comparison, private owners are, on average, less likely to have adapted their forest management practices. The percentages of having taken measures to adapt did not differ statistically significantly between groups, but forest managers tended to be slightly more proactive than forest owners ($p < 0.05$; Table 2). Those respondents who indicated that they have not taken measures to adapt were further asked to mention the reasons for their inaction (Fig. 3). Of these 222 respondents, a large

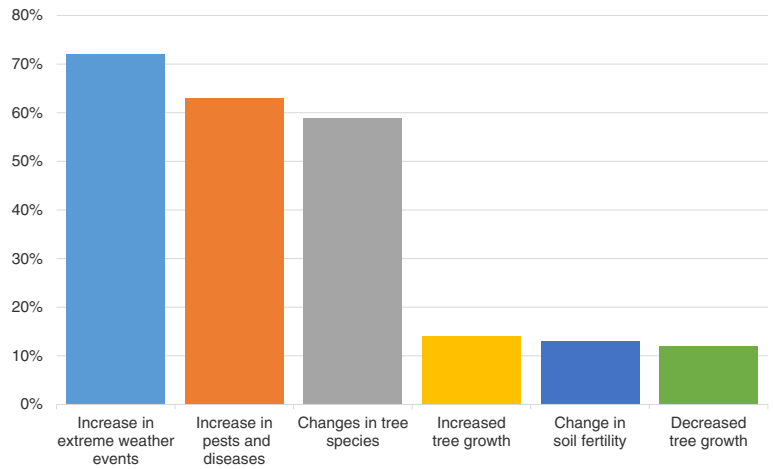

Fig. 1 Expected impacts of climate change on forests. Percentage of respondents who answered to the question: *How do you think your forests will be affected?* (*N* = 358)

majority considered lack of information and technical assistance (64 %) as major constraints. The least selected constraint was lack of interest in implementing climate change measures (5 %). Respondents also considered lack of conviction that adaptive actions are important as a major constraint.

Following on from the constraints to adopt adaptation measures, respondents were asked what assistance they would require to address climate change. The most selected options were improved access to technical information (47 %) and improved public awareness on forests and climate change (46 %).

Among the respondents who stated that they had made changes to their forest management options to address climate change, 96 % said they have promoted the establishment of mixed stands and 92 % said they have planted better adapted species or varieties (Fig. 4). Only 5 respondents said they have purchased an insurance against damage.

Modelling adaptation to climate change

Finally, we used logistic regression to investigate if experiences and beliefs in climate change can explain differences in attitudes and motivations for adapting forest management to climate change. We first tested the effect of the belief in climate change on the propensity to adapt, and then we fitted a model based on both beliefs and experiences of respondents with regard to climate change (Table 4; see also Blennow et al. 2012). However, the overall explanatory power of both models was poor ($\chi^2 = 7.665$, DF = 1, $p = 0.006$ and $\chi^2 = 12.448$, DF = 1, $p = 0.002$, respectively).

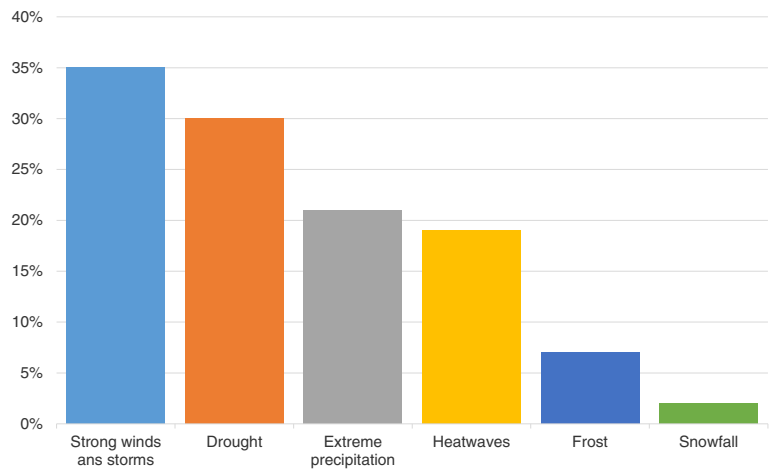

Fig. 2 Experienced climate change related (or perceived) extreme events. Percentage of respondents who answered to the question: *What are your experiences of extreme weather events in your forests that you interpreted as caused by climate change?* (*N* = 195)

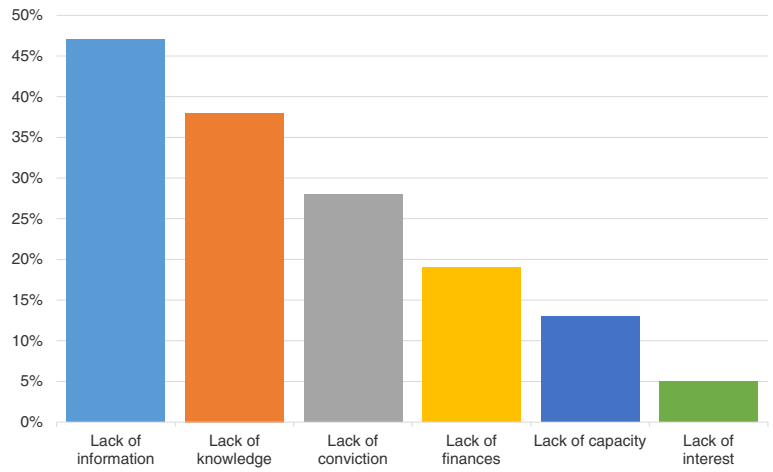

Fig. 3 Constraints limiting climate change adaptation. Percentage of respondents who answered to the question: *What are the greatest constraints limiting your ability to undertake climate adaptation actions?* (*N* = 222)

In this final step of the analysis, the model with the best fit included variables describing respondents' belief in climate change and that forest managers need to be proactive in their climate change actions, a positive effect of climate change on tree growth, as well as variables describing constraints to implementing these actions (hereafter referred as full model; Table 4). Constraints to responses include lack of knowledge, lack of finances, lack of interest, lack of information and lack of capacity (Table 3). This model fits the data significantly better than the models based on both belief variables (Table 4), and is statistically more reliable than the intercept only model ($\chi^2 = 312.80$, DF = 9, $p < 0.0001$).

Discussion

Climate change presents significant risks for forests and challenges for forest stakeholders. Therefore, gleaning their perspective on climate change effects may help policy makers to better assist forest stakeholders to effectively respond to climate change challenges and opportunities over the long term.

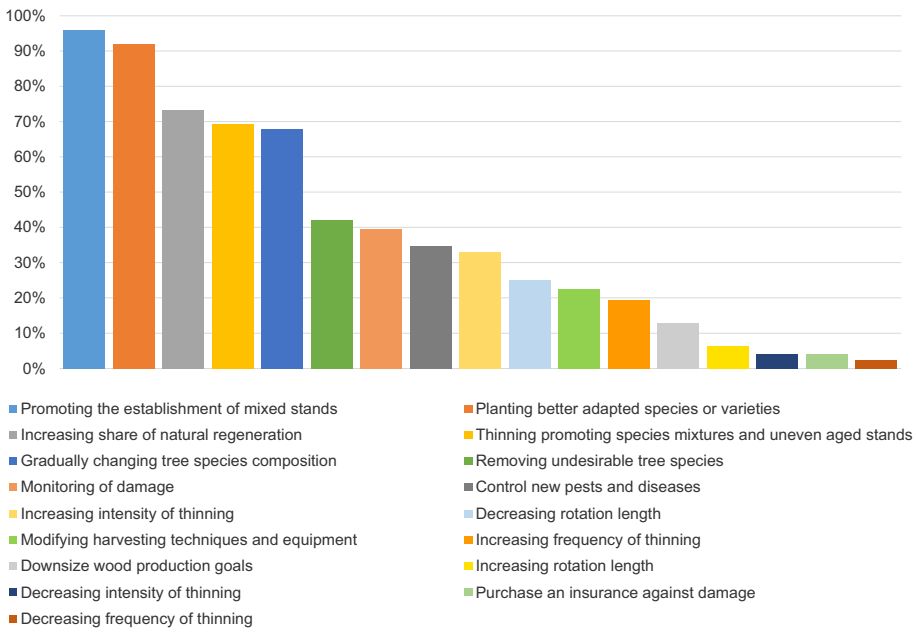

Fig. 4 *Potential adaptation options for forestry. Percentage of respondents who answered to the question:* How do you think you have adapted your management practices? *(N = 169). The legend should be read from left to right and top to bottom*

Table 4 AIC and coefficients of discrimination (*D*) values of the different forms of the model fitted to the dataset using logistic regression

	AIC	*D*
Adaptation—Belief	484.86	0.01
Adaptation—Belief + Experience	482.12	0.03
Full model	**196.29**	0.65

The value in bold is the most parsimonious model as selected by AIC comparison (ΔAIC > 2)

Because the belief in local effects of climate change has often been linked to more support for climate change actions (e.g. Blennow et al. 2012; Yousefpour et al. 2013), our study started by asking the stakeholders whether they believed in climate change. Not surprisingly, a large majority (95 %) of respondents said that they believe climate change is occurring. Furthermore, they are concerned that it will affect them. This tendency is not new, but it has seldom seen so strong before. But ultimately, as the planet continues to warm, the issue of whether they believe in climate change will become more and more irrelevant.

In this respect, Blennow et al. (2012) suggest considering the combined effect of both personal beliefs and experience to better explain and predict adaptation to climate change. This was also observed by Seidl et al. (2016) and Ameztegui et al. (submitted). Indeed, many forest stakeholders have come to link climate change with recent extreme weather events, such as heat waves and storms, which are expected to become even more pronounced throughout the 21st century (ECORES and TEC 2011; Brouwers et al. 2015). Yet, although a consensus has been reached, we found that the understanding that climate change is happening and poses a worrisome threat is not synonymous with adjustments to management plans and practices.

Adaptation in forest management

Adaptation to climate change represents new challenges for forest stakeholders, in addition to current economic, social, and political challenges. The implementation of adaptive practices into forest management is best achieved by fostering a shared understanding of the task at hand among the plurality of practitioners (Keenan 2015). However, what is more startling is that 71 % of respondents perceive that their forests are at risk from climate change but are ambivalent about the importance of implementing adaptation measures. Moreover, only just over half of those who said that forest management will need to adapt to climate change have taken measures to adapt. As noted already, the awareness of climate change did not translate into adaptive management practices, which is even more meaningful when considering that those who answered to our questionnaire are mostly well-educated and have an extensive forest management experience (over 15 years). Moreover, even though small forest ownership may be underrepresented in our sample, this reflects the fact that the survey was targeted mainly on those forest owners and managers who are actively engaged in forest management. Therefore, if on the one hand, we may not have reached many of those owners whose residence is in or adjacent to the forest, which is often considered an extension of their garden, and are therefore less engaged in the issue of climate change than those managing their forests; on the other hand, it adds meaning to the results. The owners we indeed reached are expected to be those most strongly affected by the impacts of climate change on forests and who could play a lead role in the implementation of adaptation actions. So, what is preventing them from taking measures to adapt to climate change?

Adaptation is, in essence, about making the best possible decisions for the future, taking into account the implications of climate change (Keenan 2015). It requires considerable knowledge, competence and commitment for adopting actions, but also embracing risk and uncertainty (Howlett 2012). As to the later, Hallegatte (2009) proposes to implement 'no regret' strategies, which yield benefits even in the absence of climate change. It is implausible that a single 'right' decision is 'right' for all circumstances, but 'we can buy time while we learn more' (Bellassen and Luyssaert 2014). Accordingly, comparing options from available adaptation measures will be key to successfully adapting forest management to the challenges of climate change (Kolström et al. 2011). But, although much has been written about adaptation strategies in forestry (e.g. Lindner et al. 2010; Kolström et al. 2011; Keenan 2015), and a number of recent guidance manuals to assist forest managers have been developed (e.g. Lindner et al. 2008; Peterson et al. 2011; FAO 2013), there is still a major knowledge deficit among forest stakeholders. This is consistent with our results: a higher proportion of Belgian forest owners and managers highlighted the lack of information and technical knowledge to undertake climate change adaptation actions as their main constraints to implement these actions. Furthermore, the minor importance given to the lack of interest when compared to the other constraints indicated that it is not lack of willingness which prevents forest stakeholders from implementing these actions, whereas the lack of conviction in its importance is very likely linked to their lack of knowledge. And although many respondents (20 %) consider the future situation too uncertain to undertake adaptation actions, the reason for not having adapted among believers of climate change is most often related to the lack of knowledge on how to

adapt rather than to uncertainty about the climate change *per se*. Blennow and Persson (2009) came to the same conclusion in a study among Swedish private forest owners.

But the view that the problem is merely a knowledge deficit is not correct - it is also a knowledge transfer problem. Climate change has received increased attention by researchers and policy makers (see, for example, Spittlehouse and Stewart 2004; Lindner et al. 2010; Keenan 2015; Seidl et al. 2016), but more knowledge does not necessarily translate into greater acceptance, nor into behavioural change (Kahan et al. 2012). Research and knowledge development must be coupled with effective communication in order to be successful (Morin et al. 2015). For example, regarding the performance of mixed *versus* pure stands, Carnol et al. (2014) have shown a discrepancy between the perceptions of practitioners and the scientific knowledge on the issue of productivity in mixed species stands, urging to the need to address the lack of scientific data and to improve the communication of the topic towards practitioners through efficient information flow.

Indeed, there has, perhaps, never been a greater need for the sharing of information, knowledge and experience among researchers, policy makers and practitioners than right now. In fact, as pointed out by Keenan (2015), effective climate change adaptation is best achieved by combining scientific and local forest knowledge and by making this knowledge widely accessible. When preferred adaptation options have been identified, which should be done in close consultation with all stakeholders involved in the adaptation process, climate change guidelines for forest managers shall provide descriptions of steps taken or envisaged to implementing these actions to ensure maximum responsiveness to climate change impacts on forests.

Adaptation strategies and ongoing measures

In our study only 30% of respondents stated they had already taken action to address climate change. Among the adopted measures, the conversion to mixed species stands better adapted to the prevailing site conditions ranked highest, either between public or private managers. On the other hand, selecting and introducing species better adapted to future warm conditions is preferred by private owners. Many respondents also reported that they have increased the share of natural regeneration of their forests, particularly those who manage public forests. Nevertheless, the current practices are still dominated by even-aged monocultures established by artificial regeneration, e.g. in the Ardennes, where large monocultures of coniferous species occupy sites that would naturally support mixed broadleaved forests.

Recently, a few studies have been published on implementing adaptation within the Belgian forest sector (e.g. Laurent et al. 2009; Demey et al. 2015; Van der Aa et al. 2015), but to date this has not yet been translated into concrete forest policy, neither have the recommendations contained in these reports pursued further nor implemented. Furthermore, at the time being, a fully comprehensive adaptation plan has yet to be developed, which is urgent considering that even those respondents who recognise the need to adjust their forest management practices to meet the needs for adaptation for climate change, do not know how to adapt to these changes.

As the final step, we have attempted to test the hypothesis proposed by Blennow et al. (2012) that strong beliefs in local effects of climate change and in having experienced climate change are sufficient for accurately explaining and predicting adaptation to climate change. Our results, however, do not support this hypothesis. Unlike the full model, models based only on the two personal belief variables do not account for the variability in predicting adaptation to climate change. There are several plausible reasons for this. Most significantly, European forests are extremely diverse in terms of their biophysical and socio-economic conditions (Kolström et al. 2011). As a result, adaptation in forest management may differ in particular between intensive forestry countries, such as Sweden, and countries where the direct economic output from forestry is less important and forests are managed for ecosystem services other than production (Keskitalo 2011). In Belgium, where the contribution of forestry to the GDP is very marginal, the importance of sustaining biodiversity and natural ecological processes alongside production-oriented forestry is worth mentioning.

Therefore, we conclude that, to explain and predict adaptation to climate change, the constraints limiting forest management adaptation to climate change must be considered and addressed to make change successful. In particular, there is a need to ensure that all stakeholders have the information and tools they need to make decisions on their forest management options to address climate change.

Conclusions

Our findings suggest that there is a marked imbalance between the great awareness about climate change impacts and the adaptation measures put into practice on the ground. In order to tackle climate change challenges, it is important to provide capacities and support to the forest sector. The research presented in this paper provides evidence that despite the many uncertainties associated with climate change, forest stakeholders in Belgium show great awareness of the need to adjust forest management practices to meet the needs for adaptation to climate change. However, this finding contrasts with the perceived lack of knowledge on how to adapt.

Improving communication of adaptation challenges and strategies for climate change adaptation is therefore likely to be the most effective approach for increasing action, which should also be the focus of future research.

Acknowledgments
We would like to thank all the respondents who participated in this study, and the forest groups for helping us collecting responses from their members. We also thank Thomas Van de Peer, Bruno Verbist and Mariella Marzano for their assistance with the survey design and four anonymous reviewers for their valuable comments on earlier versions of the manuscript. This research was funded by BRAIN.be, Belgian Research Action through Interdisciplinary Networks, in the framework of the FORBIO Climate project.

Authors' contributions
RSS participated in the design and organization of the survey, oversaw data collection and its analysis and drafted the manuscript. QP, KV and BM participated in the survey design and coordination and reviewed the manuscript. AVH provided guidance and review of the manuscript. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

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Received: 7 June 2016 Accepted: 7 September 2016
Published online: 16 September 2016

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