Preliminary results –

Please, do not quote without permission from authors

Wood ash recycling in forest and French forest owners' stated preferences

– A discrete choice experiment

Jens Abildtrup[1], Anne Stenger[1,2], and Laurent Saint-André[3]

[1]LEF, INRA, Nancy

[2]BETA ,Université de Strasbourg

[3]BEF, INRA, Nancy

March 2017

Abstract

Wood fuels are an important energy source in meeting EU's renewable energy targets. The increased demand for wood fuels has been seen as an opportunity to increase the profitability of forest management by exploiting hitherto unexploited resources in France. However, the increased use of wood fuel generates also several environmental issues, including the export of nutrients through residues and stump harvests and thereby potential negative impact on forests' long-term forest productivity. Ash-recycling has been suggested a sustainable remedy for the loss of nutrients. While ash-recycling in forests is not currently allowed in France, law-makers are considering new legislation allowing ash-recycling in forest. The present study analyses forest owners' stated preferences for ash-recycling based a survey of forest owners in three French regions carried out the fall 2016. Applying a discrete multi-attribute choice experiment we estimate forest owners' willingness to pay for having ash being spread in their forests. We find that forest owners, in average, have a positive willingness to pay for ash-recycling in their forest but it depends on the applied technology, origin of the ash and the expected impact on productivity of forests as well as the characteristics of their forests.

Preliminary results –

Please do not quote without permission from authors

Wood ash recycling in forest and French forest owners' stated preferences

– A discrete choice experiment

March 2017

Abstract

Wood fuels are an important energy source in meeting EU's renewable energy targets. The increased demand for wood fuels has been seen as an opportunity to increase the profitability of forest management by exploiting hitherto unexploited resources in France. However, the increased use of wood fuel generates also several environmental issues, including the export of nutrients through residues and stump harvests and thereby potential negative impact on forests' long-term forest productivity. Ash-recycling has been suggested a sustainable remedy for the loss of nutrients. While ash-recycling in forests is not currently allowed in France, law-makers are considering new legislation allowing ash-recycling in forest. The present study analyses forest owners' stated preferences for ash-recycling based a survey of forest owners in three French regions carried out the fall 2016. Applying a discrete multi-attribute choice experiment we estimate forest owners' willingness to pay for having ash being spread in their forests. We find that forest owners, in average, have a positive willingness to pay for ash-recycling in their forest but it depends on the applied technology, origin of the ash and the expected impact on productivity of forests as well as the characteristics of their forests.

1. Introduction

Wood fuels are an important energy source in meeting EU's renewable energy targets and are explicitly mentioned in EU's target to reach 20% share of energy derived from renewables (EU 2009). Wood fuels include fuelwood (trunks, whole tree) from short to very short rotation dedicated plantations, harvest residues from thinning and final felling, and wood residues from the forest product industry. The latest report on European bio-economy from the Standing Committee on Agricultural Research (SCAR) and the European Bio-economy Panel (European Commission 2014) also identified sustainable biomass production as main topic. They both emphasized that the increasing demand for biomass will require new and smart production systems especially designed to ensure high levels of wood production while remaining sustainable. The increased demand for wood fuels has been seen as an opportunity to increase the profitability of forest management by exploiting hitherto unexploited resources. However, the increased use of wood fuel generates also several environmental issues, including the export of nutrients through residues and stump harvests and thereby potential negative impact on forests' long-term forest productivity.

Ash-recycling has been suggested a sustainable remedy for the loss of nutrients. They are not viewed as some recycled waste but ash resulting from the combustion of wood has interesting characteristics to be exploited on agricultural or forestry soils: they contain calcium, potassium, magnesium, phosphorus and have a very interesting basic power even if the other hand, they may also contain non-desirable elements. The mineralogical composition as well as the presence of undesirables varies greatly depending on the species of wood, the types of soil on which the tree has grown and the type of fuel burned (wood chips, crushed pallets, etc.). The ashes can thus be used to improve the soils and to fertilize them (by the addition of potash and phosphorus). The ash has recognized fertility properties in agriculture. In France, the current regulatory framework allows agricultural spreading but does not allow ash spreading in forests), where no regulation and no norm exist. Some countries, however, practice ash-recycling in forests (Sweden, Finland for example). The experiences show that, under certain conditions, reasoned intake of ash could improve the productivity and health of forest stands.

The reflection on the spreading of ash in the forest was accelerated in France by specific measures in national wood fuel programs (e.g. ADEME 2008). Larger district power and heating plants are important users of wood fuels (Demirbas et al. 2009). This increase in demand has been seen as an opportunity, from a forest owner perspective, to increase the profitability of forest management by exploiting hitherto unexploited resources and, from a social point of view, to increase employment in rural areas (Peters et al. 2015). However, this demand for wood biomass for energy increases the competition with pulp and paper industries and more generally with new bio-products produced with wood. This raises the question about the size of potential resources and the mobilization of unexploited resources (Bjørnstad 2005; Lundmark et al. 2015). The increase in wood fuel use has also generated several environmental issues: first the generation of considerable amount of ash which mostly has been deposed in landfills and secondly the export of nutrients from forests through wood harvest. For example, in Finland and Sweden are generated approximately 260,000 tons and 300,000 tons, respectively, of ashes from power and heating plants, the pulp and paper industry and the sawmill industry (Emilsson 2006) while only a small share have been recycled as forest fertilizers, i.e. 10% and 5% in Finland and Sweden, respectively (Vesterinen 2003). The majority of the ash produced (approx. 59% in Finland) is disposed in landfills and the remaining share, not used in forests, is used in road constructions and ground work (Väätäinen et al 2011). The increased use of forest biomass, in particular harvesting of residues and stumps has raised concerns about nutrients exports, chemical and biological soil fertility and tree growth (Achat et al. 2015; Raulund-Rasmussen et al. 2008; Stupak et al. 2007; 2011). It has been suggested to fertilize forests to compensate for the loss of nutrients (Paillet et al. 2013) and that recycling of ash from the burning of wood could be one option to reduce the negative impact of biomass harvesting (Augusto et al. 2008; Väätäinen et al. 2011; Ekwal et al. 2014).

In France, ash recycling in forest is not allowed and fertilization is still a marginal forest management practice, even on acidic soils. But in Sweden, the surface area fertilized in 2012 was about 46,000ha and the surface area concerned by ash recycling was about 12,000-13,000 ha representing 30% of the annual final felling (Swedish Forest Agency, 2013). In Finland forest owners applying ash obtain a subvention (Laitinen et al 2006), like in Sweden where ash was subsided until 2004. It should here be noted that the removal of subsidy did not reduce ash-recycling but did in fact increase with more than 100% between 2004 and 2011 (Swedish Forest Agency 2013). However, it is not only long-term wood production and soil fertility but also the provision of other forest ecosystem services which may be influenced by increased biomass harvest which may change the biogeochemical cycles (Verschuyl et al 2011) and by the application of ash-recycling which may contain undesirable elements such as heavy metals (Pitman 2006; Karltun et al. 2008; Bouget et al. 2012, Huotari et al. 2015).

To establish a solid base for developing new legislation, allowing, or supporting, ash-recycling it is important to study forest owners' behaviors and acceptance towards new ways of producing. One will expect forest owners to choose, if well-informed, the profit/utility-maximizing practices. However, they will not necessarily choose the practices maximizing social welfare nor consider the long-term fertility effects of biomass harvesting due to, for example, incomplete information. Therefore, the private owners' management choices (including ash recycling) may not be socially optimal and policy intervention is necessary.

The objective of the paper is to capture French forest owners' willingness to adopt a new technology through the estimation of the willingness to pay for ash-recycling in their forests. This paper is the first study to assess forest owners' preferences for alternative scenarios of ash-recycling through stated adoption of ash recycling practices. The application of stated preference methods is, in particular, relevant in the present case where we cannot observe forest owners behavior with respect to ash-recycling. Therefore, this article shows the results of a survey which includes a discrete Choice Experiment (CE) on 210 forest owners in 3 forest regions in France. The CE method is a survey-based method that makes it possible to model individual's choices among scenarios (alternatives) that are characterized by multiple attributes. The CE method has the advantage of quantifying how different attributes or factors influence choices which provides important information for policy. By including monetary attributes (costs) it is possible to estimate the marginal value of non-monetary attributes in monetary terms. It is widely used method in, for example, economic valuation environmental scenarios, in valuating new treatments in health-economics or infrastructure investment in transport economics. In our case, the origin of ash, the impact of ash-spreading on productivity, the spreading equipment, the cost of spreading are considered as the main attributes, influencing the acceptability of ash recycling by forest owners.

In what follows, Section 2 examines the determinants of ash-spreading acceptability in the population of forest owners. Section 3 provides the main elements of the study design, including the area, the design of CE and the questionnaire. Section 4 focuses on the implementation of the survey. Section 5 outlines the sample's characteristics, mainly towards ash-spreading. Section 6 presents the main results from the CE method as well as the derived welfare estimates and Section 7 discusses and concludes.

2. Potential determinants of ash acceptability in French forests

Based on discussions with forest managers and advisor, we expect that at least four determinants could impact ash forest owners' acceptability. The first one considers the impact of ash on forest productivity. By productivity we understand the forest stand timber production during a rotation. From experimental studies we know that the productivity effects will depend strongly on soil type, tree species and potential enrichment of the ashes. In the present study we only consider ash coming from wood boilers and do not contain heavy metals originating from for example burning of waste. The technical solutions to the spreading of ashes may also influence the acceptability. There are two main types of spreading ash: Land application (with tractor) is the least expensive method for surfaces up to a few tens of ha, but requires a well-established network of access and partitioning. It requires load-bearing soil conditions to limit the risk of settlement, unlike helicopter spreading which represent the alternative main technology for ash spreading. The origin of ash is a third determinant. Ash can either be from local sources or without any geographical restrictions. We expect some forest owners will prefer local sources as this is mostly in line with perceptions of sustainable management and furthermore ash from local harvested trees means that minerals return will more likely correspond to the minerals removed by harvesting. The last determinant but obvious determinant is the cost of ash application in forests. These costs are the sum of purchase cost of ash, transport costs, spreading costs, technical file, other administrative costs. From this potential subsidies should be substracted.

3. Study design

a. Study location

We targeted members of the three French forest owner co-operatives that are mainly located in the West of France (North and South) as well as in the Center: COFOROUEST, UNISILVA, and CFBL. The reason for targeting members of forest co-operatives is that member of a forest co-operative are typically having an active forest management and therefore be potential user of ash-recycling. It should be noted that there is a very large number of very small forest owners in France. More than two million forest owners with forest less than 1 hectare and a large share of these are not carrying out any active management of their forest (AGRESTE 2015). Therefore, it is very unlikely that these small owners will adopt ash-recycling. Furthermore, previous experiences show that these passive owners will rarely respond to surveys concerning their forest (Petucco et al. 2015).

b. Questionnaire design

The first version of the questionnaire was developed by the research team together with representatives from the forest co-operatives and experts from the French forest service. The first version of the questionnaire was sent in paper form to the co-operatives to receive first comments from the technician having daily contact with members. A second version of the questionnaire was again send to the three forest co-operatives participating in the project and two forest owners were in each co-operative ask to respond to the questionnaire while the technician where next to them to observe and debrief the forest owners. Each technician reported their observations. The questionnaire was modified accordingly. The modifications concerned mostly the description of attributes and the introduction to choice experiment.

The final questionnaire comprised 4 parts: the first one explained the context of ash-spreading in France and notably that wood is a renewable and recyclable material with multiple uses, including energy and the development of renewable heat production from wood biomass in the national objectives. The ash contains nutrient mineral elements and has recognized fertility and fertility properties in agriculture. In France, the current regulatory framework allows agricultural spreading but does not allow ash spreading in forests. Some countries, however, practice these applications in the forest with a period of several years (Sweden, Finland for example). These experiments show that, under certain conditions, reasoned intake of ash could improve the productivity and health of forest stands.

In the second part, individuals were asked if they had considered ash recycling and if yes why (To compensate for the export of mineral elements when harvesting timber; To increase stand productivity; To upgrade waste with basic and nutritional properties (such as a commercial calcium magnesium amendment); To manage soil fertility; To improve the health of stands). Then in a third part, forest owners were confronted to 6 choices and to give for each their preferred option. The last part asked forest owners to give some characteristics on their forests as well as their socio-economic information such as level of education, age, job.

c. Design of CE

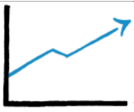
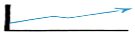
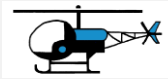
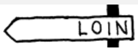
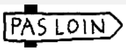
As introduction to the CE it was explained that the respondent would be presented for different scenarios and they would be asked to choice the scenario they prefer. This would be repeated six times and in each choice situation they could choose between the current situation, i.e. not having ash spread in their forest and two hypothetical scenarios involving ash recycling. The hypothetical scenarios deviate with respect to four different attributes, explained in text and with illustrations. In Table 1 the attributes and their levels are listed. The first attribute concerns the impact on productivity of ash-recycling. They were told that that scientific experiments have shown that impact on productivity of ash recycling depend on the forest type, soil type and the treatment of ashes before application. Therefore, the effect is not known with certainty today but we ask them to make their choices given the different hypothesis of productivity impacts. The second attribute concerns the technology for distributing the ashes. Two main approaches exist today: helicopter or tractor born spreading. It is explained that the advantage of helicopter spreading is that there don't need to be other road access to forest and there is risk of soil compaction. On the other hand helicopter spreading requires large areas to be efficient. The third attribute is whether the ashes originate from local wood used in energy production. Finally, the fourth attribute concern the costs of application. The respondents are explained that these represent net costs, i.e. all costs associated by spreading of ash subtracted potential public financed subsidies. from these costs. The reason for presenting the costs in this way was that we wanted that the costs could be reasonable that the costs were interdepended of the other attributes. We explained that the different potential scenarios for subvention were realistic.

Table 1 Attributes and levels

Variable	Levels
Impact of ash-recycling on forest productivity.	No increase in productivity but maintaining the current productivity
	5 % increase in productivity
	10 % increase in productivity
	15 % increase in productivity
Technology for spreading of ash	Tractor based spreading
	Helicopter spreading
Origins of ashes	Local ash
	No restrictions
Costs	0 Euro per ha
	100 Euro per ha
	300 Euro per ha
	500 Euro per ha

Before the first choice set the respondents were reminded that they could choose the current situation (no ash) if no of the scenarios involving ash application were interesting for them. They were also reminded that the costs were not depended on the method of spreading, the area of application or the quality of the ashes but was determined by different levels of subsidy. An example of a choice set is shown in Figure 1

Figure 1. Example of a choice set presented to a respondent

Choice 2 Aspects	Scenario 0 Without ash	Scenario 1 Spreading of ash	Scenario 2 Spreading of ash
Impact on productivity	-	 +15%	 +0%
Method of spreading	-		
origin of ashes	-		
costs	0	 300 €/Hectare	 0 €/Hectare
Choose here →	☐	☐	☐

A D-efficient design was generated by using the software Ngene for a multinomial logit model with priors based on the pre-test results and expert knowledge. The design included 12 choice sets which were divided into two blocs of 6. Respondents were randomly assigned one of the two designs. We divided the 12 choices set into two blocks to avoid the questionnaire getting too long and too many forest owners not completing the questionnaire. This was an issues raised during the test of the questionnaire.

After the choice experiment respondents who had answered scenario 0 (with ash) in all choices, where asked why they didn't choose one of the hypothetical scenarios. The following section included several questions about the forest owners' forests and about their management. Finally, some questions on the respondent's household.

d. Econometrics

We used a choice experiment (CE) (Hanley et al. 1998) to elicit the preferences for ash-recycling among French forest owners. The CE method relies on Lancaster's consumption theory (Lancaster 1966), stating that the utility of a good, in our case an alternative scenario for ash spreading in forests, is derived from the attributes of that alternative good. Further, this is combined with random utility theory (McFadden 1974, Train 2003), where it is assumed that each individual choose the alternative among a set of alternatives that maximize expected utility. Alternatively, we could consider the maximisation of expected profit as an important choice for forest owners may be to maximise profit. However, empirical studies of French forest owners (e.g. Petucco et al . 2015) have shown that non-economic objectives (e.g. amenity provision, heritage concern) may often be guiding their management decisions. Therefore, we believe that the utility framework is relevant in our case.

Specifying the utility function in preference-space, we let respondents be indexed by *n*, their chosen scenario by *i*, the cost of the scenario by p_i and the attributes of the scenario are all included in the vector x_i. Thus the utility, *U*, of choosing a particular scenario may be described as:

$$U_{ni} = \alpha p_i + \boldsymbol{\beta}' x_i + \varepsilon_{ni} \qquad (1)$$

Here α and **β** are parameters to be estimated and ε_{ni} is the unobserved component of utility. Econometrically, this component is assumed to be a stochastic, *iid* extreme value distributed error term.

As one of our main objectives is to estimate forest owners' WTP for different alternatives we reformulated equation (1) to obtain a representation of the respondents' preferences in so-called willingness to pay (WTP) space (Train and Weeks 2005):

$$U_{ni} = \alpha\left(p_i + \boldsymbol{c}'\boldsymbol{x}_i\right) + \varepsilon_{ni} \qquad (2)$$

Here $\boldsymbol{c}' = \dfrac{\boldsymbol{\beta}}{\alpha}$ is a vector of marginal WTP estimates, each related to an attribute, an aspect, of the policy alternative in question. Notice that this implies that the WTP is estimated directly and we avoid the problem of instable marginal WTP estimates based on ratios of parameters estimated in preference-space models (Thiene and Scarpa 2009).

To account for heterogeneity in preferences and hence WTP for the different scenario attributes across forest owners, we applied a mixed logit specification. This is a flexible and computationally practical econometric model, which in principle may be used to approximate any discrete choice model derived from random utility maximization (Train 2003, Train and Weeks 2005). It allows for heterogeneity across respondents by specifying random variation in the coefficients of equation (2), $\theta = \{\alpha, \boldsymbol{c}\}$. We define the distributions of the random coefficients as $f(\theta \mid \varpi)$ where $\boldsymbol{\omega}$ denotes a matrix of parameters of these distribution. This allows us to write the unconditional choice probability of a sequence of the *T* choices $y_n = \{i_{1n}, i_{2n}, \ldots, i_{Tn}\}$ made by respondent *n* as:

$$P(y_n \mid p_n, x_n) = \int \prod_t^T \frac{e^{\alpha(p_i + \boldsymbol{c}'\boldsymbol{x}_i)}}{\sum_j e^{\alpha(p_j + \boldsymbol{c}'\boldsymbol{x}_j)}} f(\theta \mid \varpi) d(\theta) \tag{3}$$

In our application we assumed continuous normal distributions for the WTP of the scenario attributes while α is assumed to be log-normal distributed. The latter distribution is chosen to ensure that the marginal utility of cost will always be negative.

4. The implementation of the survey

The survey was data was collected through an online survey platform and a postal survey. An invitation to participate in the questionnaire was sent to the members of COFOROUEST and UNISILVA by e-mail together with the electronic newsletter in November 2016. The invitation to CFBL was send in beginning of December. The e-mail included a link to the web-based survey developed in Limesurvey software and hosted by INRA. In the case of CFBL, 528 members were sent a paper version of the question including a return letter. CFBL didn't have e-mail addresses of all members. Therefore, we included this postal based survey option for this co-operative.

The invitation was by e-mail 5122 forest owners in the three forestry cooperatives. 465 forest owners had replied via internet and eight has returned the questionnaire by letter by 18th January 2017. This gives a responds rate of 8%. An important share of these questionnaires was not completed. Only 194 questionnaires were completed (3.4%). This is a low respond rate but is not very different from other recent surveys of forest owners in France (Petucci et al 1995). Most respondents dropped out after the initial description (was a relatively long text) and at the end of the questionnaire where asking about income from forestry. However, 217 had carried out the choice experiment and were used for the estimations in below. However, based on follow up questions we excluded 7 respondents who had answered status quo in all scenarios and in the follow-up questions gave non-economic reasons for these choices. The main reason was that the choice experiment was too complicated.

5. Survey results: some sample statistics

Table 2 shows the characteristics of the sample. Forest sizes are relatively equal distributed in the interval 5 to 500 hectare. French forest owners are old corresponding to our sample where 34% are more than 70 years old. Our sample is relatively well educated with 48% having a master degree. Most forest are owned by individuals and are certified.

Table 2 Characteristics of sample

Characteristic	Interval	%
Size of forest	0-5 ha	6.86
	5-20 ha	16.18
	20-50 ha	21.08
	50 -100 ha	22.55
	100-500 ha	28.92
	>500 ha	4.41
Age	18-40	7.49
	40-55	15.51
	55-70	42.78
	>70	34.22
Gender	Male	85
	Women	15
Principable activity	Forester	11.43
	Farmer	3.81
	Self-imployed	6.19
	Higher level employee	27.62
	intermediate	1.9
	Employed	3.33
	Worker	1.43
	Retired	41.9
	Other	1.43
	Without work	0.95
Level of education	other	11.43
	No diplom	1.9
	Secundary school/Highschool (professional)	6.19
	Highschool general	6.67
	Short educatio	10
	Bachelor	16.19
	Master or higher	47.62
Ownership	Individual	55.91
	group	21.51
	indivision	18.82
	other	3.23
	Property company	0.54
Certification (FEFC, FSC)	yes	87
	No	13

6. Econometric analysis and welfare estimation

We estimated the econometrical model using dummy coding of discrete variables (spreading technology and origin of ashes) while productivity and costs were modeled as continuous variables. Table 3 show the results from estimation of the random utility model using a simple conditional logit model that we estimated initially. All attributes coefficients are different highly significant different from zero. We find that utility increases with productivity of the scenario and with use of local ashes. On the other hand the utility decreases with use of helicopter and the costs. The negative impact of costs is as expected while it is more surprising that the use of helicopter relative to using a tractor has a negative impact on utility. Remember that the forest owner is not carrying the cost of helicopter spreading. However, forest owners are, in average, not favourable of helicopter spreading, may be because it may be less precise in application. We also included an alternative specific constant. It was set to 1 for the scenarios with ash-recycling and zero for the status quo. As we use dummy coding this variable is confounded with tractor spreading and non-local ash. A significant positive ASC indicates that even without any increase in productivity forest owners have a positive utility of applying ash-recycling using a tractor and non-local ash.

Table3: Results, simple conditional logit model

Variable	Coefficient marginal utility	Standard error	P>|z|
One percent increase in productivity	0.844	0.161	0.000
Helicopter relative to tractor	0.057	0.011	0.000
Local ash versus non-local	-0.358	0.091	0.002
Constant for ash application alternatives	0.392	0.093	0.000
Cost (in 100 euros)	-0.590	0.034	0.000
Mcfadden Pseudo R2	16.68		
210 owners, 1260 choices			
LL	-1153.2959		

To account for heterogeneity of forest owners' preferences we also estimated equation (3), the mixed logit model in WTP-space (see results in table 4). We assume that the attributes are normal distributed. We find that all estimated coefficients have significant standard deviations. This indicates an important heterogeneity in preferences for ash-recycling in the sample of forest owners. This is not surprising as the feasibility of ash spreading as well as the objectives of the forest owner may influence the profit and utility of ash-recycling. As the model is estimated in WTP-space we can interpret directly the coefficient of the model as the mean WTP for ash-recycling. We find that the average payment for one per cent increase in productivity over a rotation is 10 Euros/hectare/rotation. Similarly, we find that the WTP is 83 Euros/hectare/rotation higher for tractor than helicopter spreading of ash and that the WTP for local ash is 49 Euros. Finally, the coefficient of the constant indicate that an average forest owner is willing to pay 187 Euros/hectare/rotation for non-local ash spread with tractor even then there is no impact on productivity.

Table 4 Results, WTP-space estimations, accounting for stochastic forest owner heterogeneity

Variable	Coefficient (marginal WTP in euros)	Standard error	P>|z|
One percent increase in productivity	10.39	1.89	0.000
Helicopter relative to tractor	-83.48	17.53	0.000
Local ash versus non-local	49.09	16.05	0.002
Constant for ash application alternatives	186.94	25.35	0.000
Standard deviation			
Productivity increase	16.73	2.16	0.000
Helicopter relative to tractor	164.66	19.24	0.000
Local ash versus non-local ash	119.76	17.66	0.000
Constant	217.96	24.21	0.000
210 owners, 1260 choices			
LL	-952.61987		

Finally, we have investigated if it is possible to explain preference heterogeneity of forest owners with observed and stated characteristics of the forest and forest owner. These characteristics are interacted with the attribute variables in the utility function. Three variables are used. The first is the share of coniferous forest, second is the a dummy variable for having nature and environmental protection as main objective and the third variable is a dummy variable for expected to harvest more wood if ash recycling is implemented (see Table 5). Table 6 presents the results of the estimations with interaction terms. Other variables and interaction terms have been tested and these results can be requested from the authors. The results show that forest owners with a high share of coniferous forests have a significant higher WTP of a productivity increase. Furthermore, the WTP for helicopter spreading is significant lower for coniferous forest than other forest types (broadleaves, mixed forest, etc.). For these other forest types the WTP for helicopter spreading is no longer significant. This result make sense, as it is typically more easy access to coniferous forests (e.g. trees in rows) than broadleaves or mixed species forests. We find that for owners having nature and environmental protection as principal objective will pay more for local ash. One can speculate that this is because they consider sustainability as important. Finally, we have that the WTP for ash recycling (cf. the coefficient of the constant) increases with the expectation about higher harvest. In other words, owners believing that ash recycling will increase productivity and thereby income from harvest will pay more.

Table 5 Descriptive statistics: forest owner and forest characteristics.

Variable	mean	St deviation	max	min
Share of coniferous forest	37.23	34.91	0	100
Management objective 1 if nature and environmental protection is the principal objective, otherwise 0	0.10	0.30	0	1
If agreeing with the statement: “they will harvest more if they implement ash-recycling to manage their soil fertility” this variable is 1, otherwise 0	0.48	0.50	0	1

Table 6 Results, WTP-space estimations accounting for deterministic and stochastic forest owner heterogeneity

Variable	Coefficient (marginal WTP in euros)	Standard error	P>|z|
One percent increase in productivity	6.552	2.495	0.009
Helicopter relative to tractor	-35.163	23.866	0.141
Local ash versus non-local	44.925	16.776	0.007
Constant for ash application alternatives	115.515	31.375	0.000
One percent increase in productivity * % conifer forest	0.089	0.044	0.045
Helicopter relative to tractor * %conifer forest	-1.082	0.446	0.015
Local ash versus non-local * nature objectives	96.701	49.299	0.050
Constant*harvest more if ash recycling	123.462	39.553	0.002
Standard deviation			
Productivity increase	-14.709	2.065	0.000
Helicopter relative to tractor	-154.554	18.547	0.000
Local ash versus non-local ash	-120.236	17.581	0.000
Constant	207.919	23.378	0.000
200 owners, 1200 choices			
LL	-887.51013		

Based on the results in table 4 we have calculated the WTP for some scenarios:

No productivity gain, using tractor and non-local ash :	186.94 €/ha/rotation
No productivity gain, using helicopter and non-local ash :	103 €/ha/rotation
No productivity gain, using tractor and local ash :	236€/ha/rotation
15% productivity gain, using tractor and local ash:	392 €/ha/rotation

7. Discussion and concluding remarks

We have shown that forest owners' preferences for ash-recycling scenarios can be revealed through a survey and applying a discrete choice experiment. We find that in average forest owners have significant positive WTP for ash-recycling, ranging from about 100 to 400€/ha/rotation depending on the scenario. These estimates include costs of all activities related to ash-recycling. We have shown that the effect on productivity is an important determinant of ash application. Therefore, it is important that future research provide solid estimates of the productivity impact of ash-recycling. We find also that in average the WTP is significant higher for tractor spreading and of local produced ash. Furthermore, we find that the WTP depends on the type of forests. For example, forest owners with coniferous forests have a significant higher WTP than owners with other forest types. Future analysis will analyse more in detail the sources of a significant heterogeneity between forest owners. Understanding this heterogeneity will help policy-makers to make targeted regulations and the wood-ash chain to develop attractive solutions to different types of forest owners.

… Today, it is widely recognized by researchers and policy-makers that an ecosystem services approach is a useful framework for analyzing climate changes, management practices, land use regulations etc. (Millenium Ecosystem Assessment Panel 2005; Polasky et al. 2011; Filyushkina et al. 2015; Guerry et al. 2015). One lesson is that it is important to consider not only the market goods, e.g. timber, but also other non-marketed services like recreation use, carbon sequestration, drinking water provision as they represent a significant share of the benefits for human beings derived from ecosystems (Costanza et al. 1997, 2014). Furthermore, it is important to take into account the potential tradeoffs or complementarities between services (Polasky et al. 2011). In economic terms, ecosystems, including forest ecosystems, represent a multi-product production technology and the optimizing of the production should consider the interactions between these different goods and services. The same applies to the valuation of new technologies or forest management practices.

Evaluation of a new technology, like ash recycling, from a social point of view requires an integrated assessment of forest owners' behavior as well as the impact on all ecosystem values. This provides a base for evaluating potential regulations of new technologies. Such regulations may include definition of standards for the quality of ash used for recycling, limitations about how, where and when the ash may be spread, or include economic incentives. An important aspect in the assessment of the public preferences for scenarios where the impacts have a long time perspective and is associated with uncertainty is to consider individuals' perception of uncertainty with respect to the outcome and to understand how scientific information and the dissemination hereof is influencing the preferences of the population (Lundhede et al. 2015). On one hand, concerns about heavy metals and long term environmental effects of biomass harvesting and ash-recycling may be important factors determining the acceptability for these activities by the population (Riding et al 2015). On the other hand, combining biomass harvest with ash-recycling is appealing from a sustainability perspective (Stupak et al. 2011; Fritsche and Iriarte 2014).

Therefore, future analysis should analysis ash-recycling in an ecosystems service framework applying integrated models. This should also address the general population's acceptability of ash-recycling.

References

Achat, D.L., C. Deleuze, G. Landmann, N. Pousse, J. Ranger, L. Augusto. 2015. Quantifying Consequences of Removing Harvesting Residues on Forest Soils and Tree Growth – A Meta-Analysis. *Forest Ecology and Management* 348: 124–41.

ADEME 2008. National woodfuel programme 2000-2006 : activity report 2000-2007. Agence de l'Environnement et de la Maîtrise de l'Energie.

Augusto, L., M. R. Bakker, C. Meredieu. 2008. Wood Ash Applications to Temperate Forest Ecosystems - Potential Benefits and Drawbacks. *Plant and Soil* 306(1-2): 181–98.

Bjørnstad, E. 2005. An engineering economics approach to the estimation of forest fuel supply in North-Trøndelag county, Norway. *Journal of Forest Economics* 10(4): 161–188.

Bouget, C., A. Lassauce, M. Jonsell 2012. Effects of fuelwood harvesting on biodiversity - a review focused on the situation in Europe. *Canadian Journal of Forest Research* 42(8): 1446–1455.

Costanza, R., R. D'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, M. van den Belt 1997. The Value of the World's Ecosystem Services and Natural Capital. *Nature* 387(6630): 253–60.

Costanza, R., R. de Groot, P. Sutton, S. van der Ploeg, S. J. Anderson, I. Kubiszewski, S. Farber, R. K. Turner. 2014. Changes in the Global Value of Ecosystem Services. *Global Environmental Change* 26: 152–58.

Demirbas, M. F., M. Balat, H. Balat 2009. Potential contribution of biomass to the sustainable energy development. *Energy Conversion and Management* 50(7): 1746–1760.

Ekvall, H., S. Löfgren, G. Bostedt. 2014. Ash Recycling — A Method to Improve Forest Production or to Restore Acidified Surface Waters? *Forest Policy and Economics* 45: 42–50.

Emilsson, S. 2006. International Handbook From Extraction of Forest Fuels to Ash Recycling. Swedish Forest Agency.

EU 2009. Directive 2009/28/EC of the European Parliament and of the council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Official Journal of the European Union L140/16.

European Commission 2014. Where next for the global economy? The latest thinking from the European Bioeconomy Panel and the Standing Committee on Agricultural Research Strategic Working Group (SCAR). 2014 Directorate-General for Research and Innovation. European Commission.

Filyushkina, A., N. Strange, M. Löf, E. E. Ezebilo, M. Boman. 2015. Non-Market Forest Ecosystem Services and Decision Support in Nordic Countries. *Scandinavian Journal of Forest Research.* Forthcoming.

Fritsche, U., L. Iriarte 2014. Sustainability Criteria and Indicators for the Bio-Based Economy in Europe: State of Discussion and Way Forward. *Energies* 7(11): 6825–36.

Guerry, A. D., S. Polasky, J. Lubchenco, R. Chaplin-Kramer, G. C. Daily, R. Griffin, M. Ruckelshaus, I. J. Bateman, A. Duraiappah, T. Elmqvist, M. W. Feldman, C. Folke, J. Hoekstra, P. M. Kareiva, B. L. Keeler, S. Li, E. McKenzie, Z. Ouyang, B. Reyers, T. H. Ricketts, J. Rockström, H. Tallis, B. Vira. 2015. Natural Capital and Ecosystem Services Informing Decisions: From Promise to Practice. *Proceedings of the National Academy of Sciences* 112(24): 7348–7355.

Hanley N., Wright R.E. and Adamowicz V., 1998. Using choice experiments to value the environment - Design issues, current experience and future prospects. Environmental & Resource Economics, 11:413-428.

Huotari, N., E. Tillman-Sutela, M. Moilanen, R. Laiho. 2015. Recycling of Ash – For the Good of the Environment? *Forest Ecology and Management* 348: 226–40.

Karltun, E., A. Saarsalmi, M. Ingerslev, M. Mandre, S. Andersen, T. Gaitnieks, R. Ozolincius, I. Varnagiryte-Kabasinskiene, 2008. Wood ash recycling – possibilities and risks. In: Röser, D., Asikainen, A., K. Raulund-Rasmussen. I. Stupak (Eds.) 2008. Sustainable Use of Forest Biomass for Energy: A Synthesis with Focus on the Baltic and Nordic Region. Springer Science+Business Media BV: 79-108.

Laitinen, T., T. Lindh, E. Järvelä 2006. Essential aspects in developing and promoting wood ash forest application in finland. From Extraction of Forest Fuels to Recycling of Wood Ash, RECASH 2nd international seminar, Karlstad Sweden 26-27 September 2006. Proceeding.

Lancaster K.J., 1966. New Approach to Consumer Theory. Journal of Political Economy, 74:132-157.

Lundhede, T., J. B. Jacobsen, N. Hanley, N. Strange, B. J. Thorsen. 2015. Incorporating Outcome Uncertainty and Prior Outcome Beliefs in Stated Preferences. *Land Economics* 91(2): 296–316.

Lundmark, R., D. Athanassiadis, E. Wetterlund 2015. Supply assessment of forest biomass – A bottom-up approach for Sweden. *Biomass and Bioenergy* 75: 213–226.

McFadden D., 1974. Conditional logit analysis of qualitative choice behaviour. In: P. Zarembka (Editor), Frontiers in Econometrics. Academic Press, New York, pp. 105-142.

Millenium Ecosystem Assessment Panel 2005. Ecosystems and Human Well-Being: Synthesis. Millenium Ecosystem Assessment Series, Island Press, Washington, DC

Peters, D. M., K. Wirth, B. Böhr, F. Ferranti, E. Górriz-Mifsud, L. Kärkkäinen, J. Krč, M. Kurttila, V. Leban, B. H. Lindstad, S. P. Malovrh, T. Pistorius, R. Rhodius, B. Solberg, L. Z. Stirn 2015. Energy wood from forests—stakeholder perceptions in five European countries. *Energy, Sustainability and Society* 5(17): 1-12.

Petucco, C., A. Stenger, J. Abildtrup 2014. Influences of nonindustrial private forest landowners' management priorities on the timber harvest decision. *Journal of Forest Economics* 21(3): 152–166.

Pitman, R. M. 2006. Wood ash use in forestry - A review of the environmental impacts. *Forestry* 79(5): 563–588.

Polasky, S., E. Nelson, D. Pennington, K. A. Johnson. 2011. The Impact of Land-Use Change on Ecosystem Services, Biodiversity and Returns to Landowners: A Case Study in the State of Minnesota. *Environmental and Resource Economics* 48: 219-242..

Raulund-Rasmussen, K, I. Stupak, N. Clarke, I. Callesen, H.-S. Helmisaari, E. Karltun, Varnagiryte-Kabasinskiene 2008. Effects of very intensive forest biomass harvesting on short and long term site productivity. In: Röser, D., Asikainen, A., K. Raulund-Rasmussen. I. Stupak (Eds.) 2008. Sustainable Use of Forest Biomass for Energy: A Synthesis with Focus on the Baltic and Nordic Region. Springer Science+Business Media BV: 29-78.

Riding, M. J., B. M. J.Herbert, L. Ricketts, I. Dodd, N. Ostle, K. T. Semple 2015. Harmonising conflicts between science, regulation, perception and environmental impact: The case of soil conditioners from bioenergy. *Environment International* 75: 52–67.

Stupak, I., A. Asikainen, M. Jonsell, E. Karltun, A. Lunnan, D. Mizaraite, K. Pasanen, H. Pärn, K. Raulund-Rasmussen, D. Röser, M. Schroeder, I. Varnagiryte, L. Vilkriste, I. Callesen, N. Clarke, T. Gaitnieks, M. Ingerslev, M. Mandre, R. Ozolincius, A. Saarsalmi, K. Armolaitis, H. S. Helmisaari, A. Indriksons, L. Kairiukstis, K. Katzensteiner, M. Kukkola, K. Ots, H. P. Ravn, P. Tamminen 2007. Sustainable Utilisation of Forest Biomass for Energy-Possibilities and Problems: Policy, Legislation, Certification, and Recommendations and Guidelines in the Nordic, Baltic, and Other European Countries. *Biomass and Bioenergy* 31(10): 666–84.

Stupak I., B. Lattimore, B. D. Titus, C. T. Smith. 2011. Criteria and Indicators for Sustainable Forest Fuel Production and Harvesting: A Review of Current Standards for Sustainable Forest Management*. Biomass and Bioenergy* 35(8): 3287–3308.

Swedish Forest Agency 2013. Swedish Statistical Year Book of Forestry, 2013. Official Statistics of Sweden. Jönköping.

Thiene M. and Scarpa R., 2009. Deriving and Testing Efficient Estimates of WTP Distributions in Destination Choice Models. Environmental & Resource Economics, 44:379-395.

Train K. and Weeks M., 2005. Discrete choice models in preference space and willingness-to-pay space. In: R. Scarpa and A. Alberini (Editors), Applications of simulation methods in environmental and resource economics, Springer Publisher, Dordrecht, The Netherlands, pp. 1-16.

Train K.E., 2003. Discrete Choice Methods with Simulation. Cambridge University Press, Cambridge, Cambridge, 334 pp.

Väätäinen, K., E. Sirparanta, M. Räisänen, T. Tahvanainen 2011. The Costs and Profitability of Using Granulated Wood Ash as a Forest Fertilizer in Drained Peatland Forests*. Biomass and Bioenergy* 35(8): 3335–41.

Verschuyl, J., S. Riffell, D. Miller, T. B. Wigley 2011. Biodiversity response to intensive biomass production from forest thinning in North American forests - A meta-analysis. *Forest Ecology and Management* 261(2): 221–232.

Vesterinen, P. 2003. Wood Ash Recycling State of the Art in Finland and Sweden, Research Report, Giovanni Riva, CTI