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ORCHARDS PRUNING TO ENERGY – THE RESULTS OF THE ENVIRONMENTAL IMPACT ASSESSMENT OF THE NEW LOGISTIC CHAIN DEVELOPED WITHIN THE *EUROPRUNING PROJECT* – PART 2

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ABSTRACT

To determine the environmental impact, the assessment of the *Euro-Pruning* project strategy has been carried out in accordance with the checking and scooping list related to *Directive 97/11/EC*. Additionally, some suggestions and recommendations to prevent/minimize the hazard of accidents or negative interaction on surrounding have been elaborated (according to the suggested procedure in *ISO 14001* methodology: risk definition and prevention action proposal). As a consequence, the results of the inspection during the demo tests taking place in different orchards/plantations regarding the performance of the machineries operation, farmers' habits and pruning residues harvesting procedures have been presented, in order to diagnose and determine possible risks that may occur and influence negatively the local environment. Similar activities have been carried out during the storage tests and transportation processes.

Introduction

Each project during its realisation may have a negative as well as positive influence on the environment. Therefore, the European Union has agreed and published *Directive* (97/11/EC) defining a list of projects, whose implementation should be preceded by the analysis of its potential impact on the wide understood external surrounding (so called, environmental impact assessment analysis).

The environmental impact assessment (*EIA*) is a tool for decision-makers to identify potential environmental impacts of proposed projects, to evaluate alternative approaches, and

to design and incorporate appropriate prevention, mitigation, management and monitoring measures. The environmental impact assessment cannot be separated from social impacts of the project, hence the latter is considered as the key dimension of the *EIA* process. The *EIA* is also expected to help ensure protection, maintenance and rehabilitation of natural habitats and their functions (FAO, 2012).

The *EuroPruning* project aimed at turning pruning residues into a valuable fuel source by developing solutions for their harvesting, transportation and storage that will create growth in the European biofuels market. As there are many activities within this new logistic chain, their potential impact on the environment should be investigated. Therefore, the main goal of this work is to perform an analysis according to *Directive 97/11/EC* as well as the part of the methodology *ISO 14001* related to hazard definition and avoidance.

Methodology and investigation procedure

To obtain data about the environmental impact of the *PtE* logistic chain, the scoping and screening checklists according to *Directive 97/11/EC* have been analysed. Next, the results have been compiled to cover the project as a whole and the conclusions have been discussed, accordingly.

Moreover, apart from the screening and scoping checklists, the procedure included in *ISO 14001* methodology (risk definition and prevention action proposition) have been applied. The recognition of the hazards have taken place during the demonstration phase of the pruning harvesting (with the use of prototypes developed within the project: a chipper and a baler for pruning residues) in the orchards as well as during the material transportation and storage. Based on the performed observations, the potential risks for the environment have been pointed out and the proper actions for the avoidance of these incidents have been proposed.

Analysis of the results from screening and scooping checklist related to europruning project

As the *EuroPruning* project contains few steps in the whole logistic chain focused on the *Pruning to Energy* (*PtE*) strategy (which may be replicated in different places), the *EIA* scoping and screening issues were analysed according to three main selected parts (Dyjakon et al., 2014):

– harvesting process (in the orchard),
– transportation of the harvested biomass (transport outside orchards),
– biomass storage (open air conditions).

The obtained data from the activities related to the harvesting, storage and transportation processes have been analysed. The main outcome was that according to *Directive 97/11/EC*, this kind of activity is not included in the list of projects defined in the *Appendix I* and *II* of this ordinance. As a result, the *EuroPruning* project does not have to follow the *EIA* procedure in principle. Nevertheless, for new projects it is suggested and valuable to get through the screening and scoping lists included in the guidance on the *EIA* (EU Commission, 2001a; EU Commission, 2001b; EU Commission, 2001c) related to *Directive* 97/11/EC to be sure about the lack of significant negative impact of the *EuroPruning* project on the local environment.

Therefore, the main areas, that could influence the environment and have negative impact have been listed and discussed.

Local environmental impact analysis – harvesting in the orchards

During the pruned biomass harvesting in the fruit orchards, vineyards or olive plantations, the following important activities related to the environmental impact and included in the screening and scoping checklists of the *EIA* surveys have been identified and analysed:

a) **the use of materials, energy, water and other natural resources related to machinery construction**,
The construction works to produce pruning baler or chipper required the use of energy, various media and materials, but their influence is not significant. It is in the normal mechanic shop or machine builders' interest. The developed units belong to the typical agricultural machineries group used widely in agriculture. Moreover, their operation in the orchards is seasonal only and spread out on a large area, so the cumulative output is very low.

b) **actual or perceived risks to human health**,
The impact related to the engagement of the workers in that technology is not significant. Of course, some areas of hazards might be pointed out (noise, wounds and injuries, dust and fungi from biomass), because all kinds of activities in agriculture with machineries engagement carry some risks to human health. However, if the safety instructions are kept, the interaction of those potential negative factors on the workers in the orchard is not larger than in case of other standard activities. The risk is within the range of the normal agricultural works, mechanic shop or machine builders business.

c) **the use of fossil fuels by machinery (tractors)**,
The machinery uses the power given by the tractor resulting in combustion of fossil fuel (diesel, light oil etc.). However, the biomass harvesting process is seasonal and short-term (the operation time is ca. 1-2 hour/ha) (Frąckowiak et al., 2016; Dyjakon et al., 2017a). Moreover, the harvesting and chipping/baling process replaces actually the mulching or pushing-out process of the branches from orchard which was a standard procedure up to now. As a result, the use of natural resources (especially fuel) stays rather at the same level as it was before. So, the net fuel depletion might be minimal.

d) **pollutants emission caused by combustion of fuels by the machineries**,
The fuel combustion (diesel, light oil etc.) by the tractor leads to some flue gas emission to the atmosphere. However, the collection of the pruned biomass takes place only once per year (in most cases). Therefore, it is very limited in scale. The harvesting process is carried out in the agricultural areas, where the use of tractors is common. It should be underlined, that the harvesting and chipping/baling process replaces actually the mulching or removing and burning process of the branches from orchard (standard procedure, currently). As a result, the pollutants emission is at the same level as it was before. So, the changes in the pollutants emission might be minimal (Grisso et al., 2004).

e) **noise emission during the machinery operation**,
The noise emitted by the tractor or baling/chipping machinery in the agricultural area is acceptable and below the accepted limits. Taking into account only the seasonal use of these units and the limited duration time of their interaction with the surroundings the impact due to the noise is marginal.

f) **soil compaction/densification**,
Although, the passing of the tractor and baling/chipping machinery in between the rows of the trees may cause some soil compaction or densification, the fruits collection during the season, which is the main activity of the enterprise induces much higher pressures on the soil (there are few tons of fruits on the trailer) than the pruning harvesting itself. Moreover, the collection of pruning residues is not limited to specific time, so it can be done when the soil is dry and the compaction impacts are low. Therefore this impact is negligible.

g) **the removal of mineral compounds from soil due to the pruned biomass harvesting**,
The removal of wooden biomass from pruning might lead to the depletion of organic compounds and minerals from orchards (negative effect). However, in the pruned biomass there are also bacteria and fungi which left in the orchard may cause further development of the tree diseases and decrease of fruit productivity (to get rid of these factors is a positive effect). On the other hand, it should be emphasised that in practice it is impossible to harvest all the pruned biomass from the orchard (due to technical limitations). As the demonstrations tests had showed, the harvesting efficiency ranges from 65 to 90% (Frąckowiak et al., 2016, Magagnotti et al., 2013, Dyjakon et al., 2017b). This means that from 10% up to 35% of the pruned biomass may still be left in the orchard. Some minerals remain in the ashes in case of energetic use of the pruning residues. Applying these ashes back to the orchards lead to a closed cycle, limiting the losses. As a result, the final environmental effect regarding this issue may be considered as not significant (Den Boer et al., 2017a; Den Boer et al., 2017b).

h) **injury risk of the workers**,
The tractor driver and machinery operator (one person) has to follow the safety instructions during the work in the orchard. The injury risk is smaller and for sure not higher than for the other agricultural activities. The machinery construction does not increase the accident hazard. The access to the dangerous places with rotating elements of the machinery is limited. Therefore, the negative impact on the human health is marginal.

i) **the work of the farmer during biomass harvesting**,
The engagement of the workers in that process has rather only positive social impacts (employment of local citizens).

j) **additional profits due to the biomass selling for energetic purposes**,
The possibility of selling pruned biomass as a valuable fuel is a positive aspect of this technology. It increases the incomes for the orchard owner as well as supports further development of the company (new job creation etc.) and the local energy market.

Environmental impact analysis – pruned biomass storage

During the storage of pruned biomass in the form of bales or chips the following potential environmental consequences have been detected and discussed:

a) **the use of fossil fuels by machineries working in the storage site (loader, hake or tractors),**
The machineries require fossil fuel (diesel, light oil etc.) for operation. However, their operation time is quite limited in the storage place and includes the loading and unloading activities. Therefore, depletion of natural resources (especially fuel) is not significant.

b) **actual or perceived risks to human health**,
The impact related to the engagement of workers in the storage of pruned biomass products is not significant, because it is within the range of the normal activities in such businesses. Pruning residues are a scattered resource and storage is not likely to be done at large scale but at small scale. The piles are not higher than 6 meters. Not too much truck movements are to be expected. The operation time of the machineries needed to load/unload the pruned biomass as well as build the piles is rather short and seasonal. Therefore, the pollutants emission and noise is not significant and harmful for the people and the environment. The generation of dust is not expected, because of the bigger size of the wooden chips or bales.

c) **pollutants emission caused by combustion of fuels by the machineries**,
The fuel combustion (diesel, light oil etc.) by the machineries causes flue gas emission to the atmosphere. However, the operation time is limited. As a result, the pollutants emission is on a low level.

d) **noise emission during the machinery operation**,
The noise emission by machineries in the storage place is typical. Taking into account only the seasonal and periodical operation as well as location of the storage place (at relatively large distance from the residential buildings) its influence is marginal.

e) **GHG emission due to the long-term storage of biomass**,
In practice, the storage time of such biomass does not exceed 1-2 years, so the *GHG* emission during that period is marginal. During three months observation of *GHG* emissions from a pile of pruning residues (in form of chips) at the German demonstration site in Marquardt, only very low emission rates of *GHG* were registered. The emission of CH_4 and N_2O could be completely neglected, taking into considerations the presence of aerobic conditions during the storage period. Compared to other studies the emission of CO_2 was also low. Highest CO_2 emissions were measured during the first month of storage corresponding to the highest temperatures within the pile. The measurements performed during demonstration storage showed that the emission of *GHG* only played a minor role during the storage of prunings with a particle size of 8-31.5 mm (64% of all chips). This result however, should not be generalized, since the prunings under study had already a relatively low water content at the beginning of storage, which did not allow high microbial activity as reflected in other studies (Whittaker et al., 2016). Any CO_2 emissions from pruning residues may be regarded as renewable and thus not cause net greenhouse gas impacts.

f) **decomposition and rotting of biomass**,
Pruning residues are an organic material which in long term storage may decompose or rot (especially, in the open air storage conditions). Usually, in the energy market the biomass is sold within 1-2 years. The biomass is also stored on hard ground. Therefore, this process is not significant.

g) **the work of the machineries operators during the biomass loading and unloading process**,
The employment of workers in that process has rather only positive social impacts (employment of local citizens). The work conditions are typical for this kind of activities.

h) **additional incomes due to biomass handling**,
The possibility of handling with biomass as a valuable fuel is a positive aspect of this technology. It increases the incomes for the company as well as gives a space for new job creation.

i) **the variation of the biomass quality due to the mixing with impurities (sand, soil etc.),**
The uncontrolled blending of biomass with sand/soil should be avoided because it decreases the fuel quality and may lead to the financial losses. It does not influence the environment but interact on the local energy market. Therefore, the biomass should be stored properly.

j) **the risk of injury for the workers**,
The machineries operators have to follow the safety instruction during the work in the storage site. The injury risk is the same or even lower than in other technical activities because of periodical operation time. The impact is considered as not significant.

Environmental impact analysis – pruned biomass bales and chips transportation

Delivery of biomass to the storage place or final consumer (energy plant) requires its transportation which has an effect on the environment due to:

a) the use of fossil fuels by trucks,
The trucks need fossil fuel (diesel, light oil etc.) to transport biomass. Usually, the biomass should not be transported to long distances (over 50 km) because of the costs and lower heating value in comparison to coal. Therefore, although the pruning residues are a scattered and limited resource, the distances expected to be covered by the trucks to distribute the biomass are not too far. The transport of biomass is also seasonal. Therefore, the pollutants emission and noise is not significant, neither harmful for the people and the environment (they cause a relatively low harm on human health and the environment). Depletion of natural resources (especially fuel) is not significant.

b) **pollutants emission caused by combustion of fuels by trucks**,
The transportation distances are not expected to be long. This activity has also a seasonal character causing relatively small pollutants emissions (not significant).

c) **noise emission during the trucks operation**,
Pruning residues are a scattered and limited resource; thus, not too much trucks movement is expected. The transport of biomass is also seasonal. As a result, the noise is not significant neither harmful for the people and environment (they cause a relatively low harm on human health and the environment).

d) **road damages**,
Pruning residues are a scattered and limited resource. However, not too much trucks movement is expected (the distances expected to be covered by the trucks to distribute the biomass are not too big). The transport of biomass is also seasonal. Moreover, the bulk density of bales or chips is still not high enough to cause overloading of the trailer. So, the impact on roads is acceptable and far below limits (not significant).
e) **employment of the drivers**,
The additional work for truck drivers has rather only positive impact. The work conditions are typical for this kind of activities.
f) **additional incomes thanks to the biomass delivery**,
Biomass transportation is an additional source of incomes for truck drivers/truck company. It is a positive social impact.
g) **injury risk of the truck drivers**,
The work conditions are typical for this kind of activities.

Local environmental impact – risk definition and prevention action

Within evaluation of the possible environmental impact of the logistics chain and prevention of the negative consequences of this *PtE* strategy, observations during the demonstration tests were performed. As a result, the information related to the determination of the potential local environmental impact of the operations/actions following the criteria/procedure of acknowledged methodologies like *ISO 14001* were collected. Then, the improvements or actions to limit the risk of accident have been proposed.

The local environmental impact should consider the situations/cases that may happen during the operations related directly to *Europruning* strategy (pruning baling, pruning chipping, pruning bales/chips storage and transportation). The significant issues related to *PtE* strategy are as follows:
– fuel gases emission to the atmosphere during the machinery operation,
– noise emission during the machinery operation,
– soil pollution risk (i.e. by lubricant leakage from the baling/chipping machinery or tractor),
– soil erosion and densification,
– fire risk during pruning residue storage,
– fungi and bacteria development (i.e. during storage),
– *GHG* emission from soil caused by pruning taking away from the ground (i.e. changes in the emissions),
– use of natural resources (i.e. fuel for machinery),
– management of the waste created (if any),
– other local environmental issues (if any),

As the situation/case is identified the description of risk/hazard is prepared. Finally, the procedure/action to prevent/avoid this process has been proposed. The results are shown in table 1.

Table 1.
Determination of the local environmental impact related to the PtE strategy observed during the demonstration phase

Part of the logistic chain/location	**Situation/Case/ Operation**	**Description of the risk/hazard etc.**	**Improvement actions/comments/tips/recommendations leading to the avoidance of the incident**
Baling/chipping process	The branches may stick under the tractor or baling/chipping machinery and pull off the pipe with a working fluid (lubricants, breaking fluid etc.).	The fluid will spill out and may cause soil pollution.	The metal/durable plastic plate should be suspended or mounted under the tractor or baling/chipping machinery to prevent the hooking/sticking of the pruning under the machinery. The farmer should check his machinery before operation, and determine if it is properly protected.
Baling/chipping process	The metal pieces may be introduced into the rotated elements of the chipping/baling machinery	The sudden strokes or strikes of piece of metal with the rotated elements may cause a sparkle risk and ignition of the biomass. It may cause also mechanical damage of the parts of the device.	The risk of ignition of the biomass is very low because the size of the pruning baled or chipped is too large to be ignited. The moisture of the biomass also limits the fire probability. However, the farmer should pay attention during the operation in case there are any metal pieces laying on the soil to prevent damages.
Baling/chipping process	The rotating elements may break the branches and throw them out in the close surrounding	The broken small parts of branches (sticks) may hit the operator causing injury.	The operator should carry protective equipment (i.e. glasses, gloves, helmet etc.).
Baling/chipping process	The pruned biomass in the form of branches may block/jam itself in the feeding system of the chipping or baling machinery. It is especially possible, if the branches are too thick or to long	The operator may try to pull it out during the feeding system operation placing its hands in the area of operation of the rotated parts. It could cause serious injury to the operator.	The biomass collecting/feeding systems should have a reverse option of the operation to enable removing of the branches or other elements from the machinery.

Part of the logistic chain/location	Situation/Case/ Operation	Description of the risk/hazard etc.	Improvement actions/comments/tips/recommendations leading to the avoidance of the incident
Baling/chipping process	The stones may be captured by the pick-up system.	It may lead to the damage of the feeding system of the baling machinery. It may damage the chipping knives in the chipper.	The pick-up system should be equipped with sieves to get rid of the stones before the baling or chipping. Larger stones should be removed from the orchards prior harvesting process.
Baling/chipping process	In case of very dry conditions, dusting during the pruned biomass harvesting may occur.	It may have an influence on the human health.	The operator/worker should be equipped with a protective mask. This impact may be limited throughout the operation upwind (if possible).
Baling process	Wrapping up of the branches by the baler	The use of plastic rope (i.e. polypropylen material) requires its later removal before combustion to eliminate plastic utilisation and harmful pollutants emission.	The natural fibres as a rope should be used to avoid combustion problems and facilitate work of the operator (final user).
Bales/chips storage	Open air storage	Self-ignition risk of the pile leading to uncontrolled combustion of the pruning residues and pollutant emissions to the atmosphere.	The pile should be overturned periodically to limit self-heating of the feedstock. The pile should be equipped with a temperature control device (i.e. thermocouple) or the storage site should have a thermovision camera to control the temperature profile of the pile.
Bales/chips storage	Storage base	Biomass storage on the soil or other natural base may lead to the increase of biomass losses due to the decomposition process (especially, in the long term storage) and rotting.	The piles should be built on the hard base eliminating contact with natural ground or water accumulation.

Part of the logistic chain/location	Situation/Case/ Operation	Description of the risk/hazard etc.	Improvement actions/comments/tips/recommendations leading to the avoidance of the incident
Bales/chips storage	Storage base	Biomass storage on the soil or other natural base may lead to the increase impurities content in the biomass (i.e. soil or sand). In final, the quality of the feedstock is aggravated.	The piles should be built on the hard base eliminating mixing of the biomass with impurities.
Bales/chips storage	Long-term storage	If the pruned biomass will be stored to long, the decomposition process may begin and some *GHG* emissions may occur.	As a pruned biomass is an organic material it is suggested to burn the fuel within the period 6-12 months from harvesting process. This practice will lead to avoid *GHG* emission and use the energetic potential of the fuels properly.
Bales/chips transportation	Transportation distance	The longer the distance, the higher the pollutants emission to the atmosphere due to the fossil fuel combustion by the truck.	The transportation distance should be limited to the minimum.

Conclusions

The logistics chain focused on the utilisation of the biomass from fruit trees, vineyards or olive trees for heat production does not influence negatively the local environment in relation to the *EIA* requirements. The *PtE* strategy requires the application of some machineries, devices and trucks which use the fossil fuels for powering. However, the seasonal and relatively short-term character of the necessary operations or activities cause that the final environmental impact is not significant. As a result, noise and pollutants emission as well as the risk of accidents or human health are not crucial. However, it requires from the workers/farmers/drivers to follow the safety instructions and to use protective equipment (gloves, hearing protectors, protective glasses or helmets).

Harvesting of biomass in the orchards is carried out in a short period of time. The machineries used for baling or chipping of the pruned biomass require fossil fuels for operation, but the emission from their combustion has an acceptable impact. The safety of the machineries causes that the risk of accident or injury is very low. The noise emitted during

the operation is typical and normal concerning agricultural activities. In practice, it is not possible to pick-up all the branches from the soil. As a result, some organic material will be still left in the orchard which limits or even prevents soil depletion.

Pruned biomass is a scattered resource and storage is not likely to be done at large scale but rather at a smaller scale. The piles do not exceed 6 meters of height. The distances expected to be covered by the trucks to distribute the biomass are not too far as well. The operation time of the machineries needed to load/unload the pruned biomass as well as to build the piles is rather short and seasonal. Therefore, the pollutants and noise emission is not significant and not harmful for people and the environment (they cause a relatively low harm on human health and the environment). Dust generation is not expected, because of the bigger size of the wooden chips or bales. The biomass should be sold within 1-2 years to avoid rotting and decomposition of the organic material and consequently *GHG* emission. The self-ignition risk is very low as a size of chips is relatively big. Moreover, the piles built from bales enable a permanent flow of air between the branches which improves the natural drying of the biomass. Therefore, there is no risk for temperature increase and self-ignition of the pile.

Transportation of biomass takes place also only seasonally (from orchard to the storage place/consumer) and should be organised in such a way, that transport distances are reduced as much as possible. Such strategy insures low pollutants emission and minimises the impact on the environment. This strategy limits local road damages as well.

It should be marked, that pruning residues are a biomass classified as a renewable source of energy giving some added value to that technology and its environmental impact.

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GAŁĘZIE Z SADÓW NA CELE ENERGETYCZNE – WYNIKI OCENY ODDZIAŁYWANIA NA ŚRODOWISKO NOWEGO ŁAŃCUCHA LOGISTYCZNEGO OPRACOWANEGO W RAMACH PROJEKTU *EUROPRUNING* – CZĘŚĆ 2

Streszczenie. W celu określenia stopnia oddziaływania na środowisko strategii przyjętej w projekcie *EuroPruning*, polegającej na wykorzystaniu ściętych gałęzi z sadów i plantacji w celach energetycznych, przeprowadzono analizę w oparciu o zasady postępowania zawarte w dyrektywie *97/11/EC*. Dodatkowo, w odniesieniu do procedury zawartej w metodologii *ISO 14001*: definicja ryzyka i proponowane działania prewencyjne, opracowano wskazówki i rekomendacje mające na celu eliminację lub ograniczenie ryzyka wypadku czy negatywnego oddziaływania na otoczenie zewnętrzne. W konsekwencji, przedstawiono wyniki inspekcji dokonanych podczas badań testowych przeprowadzanych w różnych sadach i plantacjach drzew owocowych (obejmujących działanie pracujących maszyn, nawyki sadownika oraz proces zbierania ściętych gałęzi) pod kątem identyfikacji oraz określenia zakresu zagrożeń, które mogą wystąpić i wpływać negatywnie na środowisko. Podobne działania przeprowadzono dla procesu magazynowania i transportu biomasy sadowniczej.

Słowa kluczowe: biomasa, gałęzie, wykorzystanie energetyczne, ocena oddziaływania na środowisko