Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 113 (2017) 238 – 243

Energy Procedia

International Scientific Conference "Environmental and Climate Technologies", CONECT 2016, 12–14 October 2016, Riga, Latvia

Invasive species application in bioeconomy. Case study *Heracleum sosnowskyi* Manden in Latvia

Lauma Zihare* , Dagnija Blumberga

Institute of Energy Systems and Environment, Riga Technical University, Azenes iela 12/1, Riga, LV–1048, Latvia

Abstract

Since there is a constant battle with invasive species – *Heracleum sosnowskyi* Menden in Latvia, the case study aim is to evaluate possible solutions for the use of the hogweed and find if there is socio-economic benefit, greater added value and possibility to use it effectively in bioeconomy. The most explored aspect is hogweed use in biobutanol production. Evaluation has been determined with cost-benefit analysis and environmental impact assessment. The obtained testing results shows that producing products with higher added value is biobutanol production.

Peer-review under responsibility of the scientific committee of the International Scientific Conference "Environmental and Climate Technologies".

Keywords: herecleum sosnowskyi; hogweed; feedstock; biobutanol; invasive species; bioeconomy

1. Introduction

Since *Heracleum sosnowskyi* Manden was introduced in Latvia as a promising fodder crop, it has spread uncontrollably in many Latvian regions reaching a total area in 2016 of 10801.41 ha [1]. After implementing the state support program (VIDMProg_060406_latvanis), in 6 years' time it did not succeed as planned, the attention now is drawn to control, combat and limit the spread of hogweed dramatically [2]. This species is not only invasive and

* Corresponding author. Tel.: +371 24425944.
E-mail address: lauma.zihare@rtu.lv

Peer-review under responsibility of the scientific committee of the International Scientific Conference "Environmental and Climate Technologies".
doi:10.1016/j.egypro.2017.04.060

decreases biodiversity, but the plant has also proven to be a serious threat to human health and can provide second degree burns in case the plant sap is in contact with human skin and sunlight [3, 4].

The biggest concern is to eliminate the invasive species in Latvia and, especially on agricultural land, to prevent further spread of the hogweed. So the biggest effort has been put to find and apply the most effective method to control the species. For now, the most effective method is a combination of chemical and mechanical treatment [5, 6]. Combined control method is effective only if implemented for at least 6–7 years. If the mechanic treatment is done every week from May to October, then there is possibility to eliminate hogweed in 2–3 years' time [6].This method consists of one-time chemical use, 3 times mowing, 1-time soil milling and soil cultivation after soil milling 3 times in the growing season [5].

Hogweed can be used as fodder crop for cattle or for sheep. In Latvia cattle breeding is more developed than sheep breeding, cattle can produce more meat and cattle needs more feedstock, which means that with a lower number of animals it is possible to control the spreading of hogweed and achieve more economic benefits. However, caution must be provided for cattle health, as the hogweed sap can be dangerous, so they should be monitored of any changes in places that are not covered with hair coat – like lips, udder and nostrils. It is important that there is biodiversity in pastures and cattle get a more diverse feedstock to prevent from any internal health problems [5].

As the latest studies show, hogweed can be an effective bioresource for bioethanol or biobutanol production. Biobutanol has proven to be next generation biofuel superior to ethanol and therefore the third scenario was chosen as hogweed use in biobutanol production [5].

Biobutanol is a second generation biofuel, and it does not compete with the food market nor the fodder stock, because at the end of the production of the biobutanol, the biomass residue can make a high quality protein fodder [7].

The engineering solution for biobutanol production is fermentative technology using enzymes. The process is simplified and involves four steps: milling that destroys cells structure and neutralizes lignin, cellulose and hemicellulose hydrolysis to the conventional sugars using enzymes, fermentation using bacteria *Clostridium acetobutylicum* and butanol extraction [8]. The research about biobutanol production from agricultural waste shows that from several residues – starch, grass, green algae, hogweed, particularly hogweed has demonstrated the highest percentage of sugars: 40 % in green mass and 30 % dry mass [9].

Biobutanol is a biofuel superior to ethanol because of its similarity to conventional gasoline, it has greater density, if 1 l of gasoline can replace with 0.66 l bioethanol, than 1 l of gasoline can replace with 0.9 l biobutanol. Butanol is not corrosive and it can be transferred through existing pipelines, which is a great benefit, because there is no need to transform or invest in new infrastructure. It is now being proven an effective blend of 16 % with gasoline or diesel, but it can be used as well as 100 % fuel without any engine transformations [10, 11].

2. Methodology

The purpose of the case study was to find if there is an effective possibility to use hogweed for bioeconomy purposes by choosing three alternative scenarios with greater added value based on quantity that can be used and the main use of hogweed. As the increasingly important issue in Bioeconomy is sustainable use of the biomass [12].

Methodology is based on screening analysis that ensures detailed and strong analyses of adaptation measures.

To evaluate the scenarios first data was collected on potential bio-products and hogweed quantities. Based on these data, the best engineering solution for each alternative was found.

The most appropriate geographical location was determined based on availability of agricultural land invaded with hogweed and socio-economic aspects.

For each scenario there economic evaluation with cost-benefit analyses and environmental impact evaluation were conducted, so the possible impact on environment and climate is taken into account. Cost- benefit analyses show net present value, discounted payback time and internal rate of return as well as sensitivity analyses.

If the alternative scenario after evaluation is justified it is considered as one of the best alternatives, if there is more than one alternative to be justified, the best alternative is that with the highest economic benefit and lowest negative impact on climate or highest positive impact on environment.

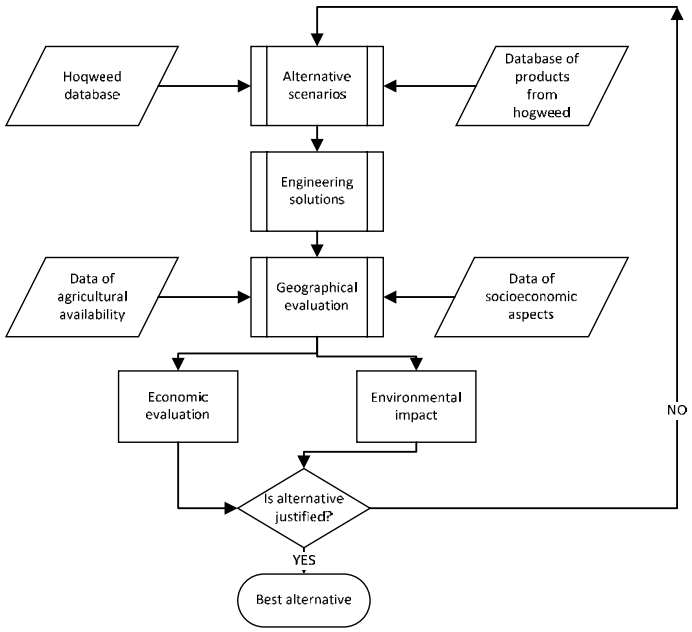

Fig. 1. Methodology for evaluation of hogweed use in bioeconomy.

3. Results

The evaluation for the greater use of hogweed has been determined and evaluated in the fallowing scenarios: scenario A – hogweed use as fodder, scenario B – combined limiting method for hogweed and scenario C – hogweed use in biobutanol production. Economic evaluation results are compared by income on one hectare of hogweed and the possible impact on the environment.

3.1. Economic evaluation results

3.1.1. Scenario A Hogweed use as fodder

The goal was to evaluate the amount of animals needed for the region with the most invasive statistics – Vidzeme region, which is in total 4445.29 ha. This region also has the largest amount of unused pasture and meadows about 30 000 ha, that can be used for cattle breeding [13].

The amount of necessary animals has been evaluated as 6667 animals to the entire region taking into account the hogweed territories 4445.29 ha and animal density 1.5 cattle on 1 hectare. The economic benefit from one cattle is 121.28 Eur, which is highly dependent on state subsidies. Total income from the region's hogweed territories using it for cattle breeding pastures is 808 574 Eur/ year, or 160.12 Eur/ha.

3.1.2. Scenario B Combined limiting method for hogweed

Economic evaluation for combined limiting method is according to average costs of process treatments and area in Vidzeme region as well as process usage per year (growth season) and labour costs.

The geographical place has been chosen the most invasive region as well, the Vidzeme region, because the treatment does not need any special requirements or do not have so many restrictions and it can be implemented on any surface. The combination is flexible, because the chemical herbicides cannot be used near water because of possible pollution or in nature protected areas, however the mechanical treatment can be implemented in these areas.

Table 1. Costs for combined limiting method.

Combined limiting method	Use per year	Area, ha	Average costs, Eur/ha	Total costs, Eur
Chemical use	1	4445.29	78	346732.6
Mowing	3	4445.29	79	1053533.7
Soil milling	1	4445.29	127,5	566774.5
Soil cultivation	3	4445.29	26,5	353400.6
Labor costs		4445.29	100	444529.0
Total				2764970.4

The total costs for eliminating hogweed in the Vidzeme region infested area is about 2.7 million Eur per year which means that in 6 years it may reach 16 million Eur. There is no direct income however, if the area is treated than there is avoidance of fine that can be counted as savings. Taking that into account, the cost of 1ha is 572 Eur.

3.1.3. Scenario C Hogweed use in biobutanol production

Hogweed can be obtained from 45 to 80 tons per hectare. It is possible to produce 50–79 l biobutanol from 1 tonne hogweed [14] which means that total production from hogweed is 2250 l/ha to 6320 l/ha. Average amount would be 4000l/ha which were used for further calculations.

Geographical location has been evaluated based on hogweed availability, best international infrastructure, social aspects (higher unemployment rate, GDP – gross domestic product), cheaper agricultural land and less territories of nature protected areas. Taking it all into account, the best geographical place is the second largest hogweed invasive region – Latgale region with a hogweed population of 2373.53 ha and from this region is possible to get 23 000 tons biobutanol per year, if the yield is mowed 3 times in growing season.

Calculations shows that it is not economically viable to produce biobutanol only from the hogweed that is in the Latgale region, however the place is more than suitable for a production plant. Further calculations were carried out to see if the production plant is economically viable if the harvest is from all Latvia regions.

As in total there is 10801.41 ha infested area in Latvia, the production of biobutanol from all these area yields would be 106 000 tons per year. Assuming that the capital investment is 57 million Eur, raw material harvest and transport costs is 26 million Eur, utilities is 43 Million Eur, operational costs is 13 million Eur, income (including income from by-products) is 29 Million Eur, the profit and taxes is about 16 Million Eur, the product price is then calculated as 0.6 Eur/kg [15].

Discounted payback time is 6 years and Net present value is 41 Million Eur and Internal rate of return is 25 %. That means that the project is economically viable if the hogweed yield includes all infested yields in Latvia and the raw material harvest is three times per year.

Sensitivity analysis shows that there is only dependence from sales amount and price, but capital investment or raw material costs do not show great impact. In the first year of payback time, the income is 1985 Eur from ha, and in 10 years' time it would be 9250 Eur/ha.

To compare, the income of Heracleum sosnowskyi Manden species in one year is 160 Eur/ha from scenario A, – 572 Eur/ha from scenario B and 1985 Eur/ha from scenario C.

3.2. Environmental impact results

3.2.1. Scenario A

Environmental impact results from the fermentation of cattle feed tract and manure management. The main two emissions CH_4 and N_2O can be prevented by constructing manure storage and use them for the production of biogas. Positive impact on the environment is the natural fertilizers that can be used to increase crop yields. Cattle can produce 6 m^3 manure within 6 months containing 3 kg phosphorus and 15 kg nitrogen and can serve as valuable organic fertilizer.

3.2.2. Scenario B

Impact on the environment and climate is mostly negative, because the use of herbicide is toxic to human health and there is a possibility of water and soil pollution which can reduce biodiversity. The positive aspect is the limiting action of the hogweed in agricultural land to allow other cultures to return in the environment.

3.2.3. Scenario C

The impact on environment from biobutanol production and use is more positive than negative, because the CO_2 that is resulting in butanol production is absorbed in the hogweed growth process and in butanol use phase it can reduce GHG- greenhouse gas emissions about 70–90 % in comparison with conventional gasoline [16]. It is also a great step towards European Union target to achieve 10 % of renewable energy usage in transport sector until the year 2020.

4. Conclusions

The methodology has been established with a complex evaluation and comparison, the algorithm of which includes a wide range of databases with different models.

The model testing is suitable for three pre-selected scenarios.

But there could be further studies taken in place based on biotechonomy concept [17].

The obtained testing results show that the highest income from 1 ha is scenario C 1985 Eur with great positive impact on environment, second best is scenario A 160 Eur/ha and with possibility to decrease a level of impact with certain actions and not beneficial is scenario B –572 Eur/ha. Proving that producing products with higher added value is biobutanol production.

There is not only economic gain, but also social and climate impact is evaluated with greater positive impact, there is a great benefit from biobutanol production – reduction of GHG emissions for 70–90 % in the transport sector. Thus from the case study it is concluded that hogweed can be an effective bio product for bioeconomy with high added value.

Acknowledgements

The work has been supported by the National Research Program “Energy efficient and low-carbon solutions for a secure, sustainable and climate variability reducing energy supply (LATENERGI)”.

References

[1] Valsts augu aizsardzības dienests, Paveiktais Sosnovska latvāņu ierobežošanā; 2016. Available: http://www.vaad.gov.lv/sakums/informacija-sabiedribai/par-latviju-bez-latvaniem/paveiktais-sosnovska-latvana-izplatibas-ierobezosana.aspx.

[2] MK noteikumi. Latvāņu izplatības ierobežošanas programma 2006.-2012.gadam. Latvija: MK426 VIDMProgr.060406_latvanis; 2006. Available: http://likumi.lv/doc.php?id=137113

[3] MacDonald F, Anderson H. Giant Hogweed (Heracleum mantegazzianum): Best management practices in Ontario. Peterborough: Ontario Invasive Plant Council; 2010.

[4] Rzymski P, Klimaszyk P, Poniedziałek B. Invasive giant hogweeds in Poland: Risk of burns among forestry workers and plant distribution. Burns 2015; 41(8):1816–1822.

[5] Nielsen C, Ravn HP, Nentwig W. Invazīvie latvāņi. Izplatība , bioloģija un ierobežošanas pamatprincipi.Teorētiskie aspekti un praktiskie ieteikumi. Hoersholma:Forest & Landscape; 2005.

[6] Gulbis G. Latvāņu ierobežošanas metožu efektivitātes salīdzināšana, rekomendāciju sagatavošana. SIA “Integrētās Audzēšanas Sk. Gala atskaite; 2013. Available: http://www.lvm.lv/images/lvm/Staratskaite.pdf

[7] Yang SKM. The use of (green field) biomass pretreatment liquor for fermentative butanol production and the catalytic oxidation of biobutanol. Chem. Eng. Res. Des. 2014;92(8):1531–1538.

[8] Natre A, Kalnins A. Atjaunojamās enerģijas konfederācija biobutanols - kā viens no nākotnes alternatīvo degvielu veidiem . Pētījums par efektivitāti un ieviešanas iespējām Latvijā, saskaņā ar ES direktīvas – 2009 / 28 / EK Saturs; 2009. Available: http://www.liaa.gov.lv/files/liaa/attachments/22_petijums_biobutanols_-_ka_viens_no_nakotnes_alternativo_degvielu_veidiem.pdf

[9] Mezule L, Dalecka B, Juhna T. Fermentable Sugar Production from Lignocellulosic Waste. Chem. Eng. Trans. 2015;43:619–624.
[10] Pfromm PH, Amanor-boadu, Nelson R, Vadlani P, Madl R. Bio-butanol vs . bio-ethanol : A technical and economic assessment for corn and switchgrass fermented by yeast or Clostridium acetobutylicum. Biomass and Bioenergy 2010;34(4):515–524.
[11] Schmitz N, Henke J, Gernot K. Biokraftstoffe - Eine vergleichende Analyse. Fachagentur Nachwachsende Rohstoffe; 2009.
[12] Muizniece I, Klavina K, Blumberga D. The Impact of Torrefaction on Coniferous Forest Residue Fuel. Energy Procedia 2016;95:319–323.
[13] Centrala statistikas parvalde. Lauksaimnieciba izmantojamas zemes platibas statistiskajos regionos; 2013.
[14] Semenovich PBS, Sodonomovich D, Gennadevna B. Bioethanol obtained from wild and domestic hogweed. RU 2010138695/04, 2012.
[15] Qureshi N, Singh V. Process Economics of Renewable Biorefineries: Butanol and Ethanol Production in Integrated Bioprocesses from Lignocellulosics and Other Industrial By-Products. Biorefineries Integr. Biochem. Process. Liq. Biofuels. Amsterdam: Elsevier; 2014.
[16] Cobalt Technologies. Cobalt Tecnologies Fact sheet; 2016. Available: http://www.cobalttech.com/pdf/cobaltfacts.pdf.
[17] Blumberga D, Muizniece I, Blumberga A, Baranenko D. Biotechonomy framework for bioenergy use. Energy Procedia 2016;95:76–80.