Environmental and Climate Technologies

2019, vol. 23, no. 2, pp. 166–186
doi: 10.2478/rtuect-2019-0062
https://content.sciendo.com

New Vision on Invasive Alien Plant Management System

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***Abstract* – Since the creation of the European Union's (EU) Biodiversity Strategy, increased attention has been drawn to the spread of invasive non-native species, their impact on biodiversity, and the economic losses caused. Ensuring compliance with the regulation on the eradication of invasive species requires financial means, therefore a new vision on invasive plant management system is proposed. With a new system, invasive alien plant (IAP) control is ensured as well as a new source of lignocellulosic biomass for product production, that could result in financial gains is presented. This article provides current alien plant situation visualization by Sankey diagram showing invasiveness of alien species and establishment, after which invasive and potentially invasive species are directed further to pre-assessment. A total of 157 invasive plant species are evaluated by multi criteria decision analysis TOPSIS, the case on the national level (Latvia) is presented and a new concept for a IAP management system is provided. The research results and the new concept provide a contribution to policy makers, land owners affected by invasive species and municipalities.**

***Keywords* – Biodiversity; bioresources; invasive alien species; invasive plant species; MCDA; sustainable management; TOPSIS**

1. INTRODUCTION

Globalization has integrated widely dispersed human communities into a worldwide economy. This process provides many benefits through the movement of people and goods, but also leads to the intentional and unintentional transfer of organisms among ecosystems that were previously separate [1].

Since the creation of the European Union's (EU) Biodiversity Strategy, increased attention has been drawn to the spread of invasive non-native species, their impact on biodiversity, and the economic losses caused which in the EU sum up to around EUR 12.5 billion per year [2]. Since the implementation of the strategy, policy measures have been continuously improving i.e., legislative instruments for limiting the introduction and adaptation of such species and their eradication. Regulation No. 1143/2014 of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species prescribes that „*in the event that eradication is not feasible or the costs of eradication outweigh the environmental, social and economic benefits in the long term, containment and control measures should be applied*" [3]. If a well-designed methodology including both eradication and environmental/social and economic benefits would be developed and applied, this problem would be solved. Both ensuring compliance with the regulation and pursuing the eradication of the invasive species require financial means, however the new vision of the

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invasive plant management system would actually ensure financial gains. Similarly to other studies, that aim to add value to low quality and underused biomass, such as common reed, cattail, sedges [4], potato peels [5], forest residue [6] and agricultural waste (grasses, vegetable silage, etc.) [7].

Previous studies have shown that the spread of invasive species and their management is a topical issue all around the world. So far the European Union co-funded projects regarding invasive plants have focused on monitoring – through the development of databases and networks [8]. A growing trend in scientific literature is to focus studies on the use of certain invasive plants for the production of various products, in particular high value-added products for the pharmaceutical and cosmetics industries [9]–[16]. On the other hand, the planning documents and regulatory enactments that apply to invasive plants follow a tactic of elimination of the consequences, i.e., restrictions, sanctions and control or eradication of invasive plants [17]. Therefore, invasive plants are considered as a problem that requires financial resources to solve it, but the potential benefits of invasive plants are only recognized by scientists on a theoretical level and are rarely implemented in practise. All invasive plants are basically bio-resources that can be used in all sectors of the economy as any other bio-resource, and can provide economic, social, environmental and climate benefits when used sustainably. While also emphasizing the fact that deliberate cultivation of invasive plants is not permissible, the sustainable use of bioresources for production of products, including products with high added value, is described by the bioeconomy concept, the implementation of which has become particularly topical in the last 7 years since introduction of the EU Bioeconomy Strategy [18].

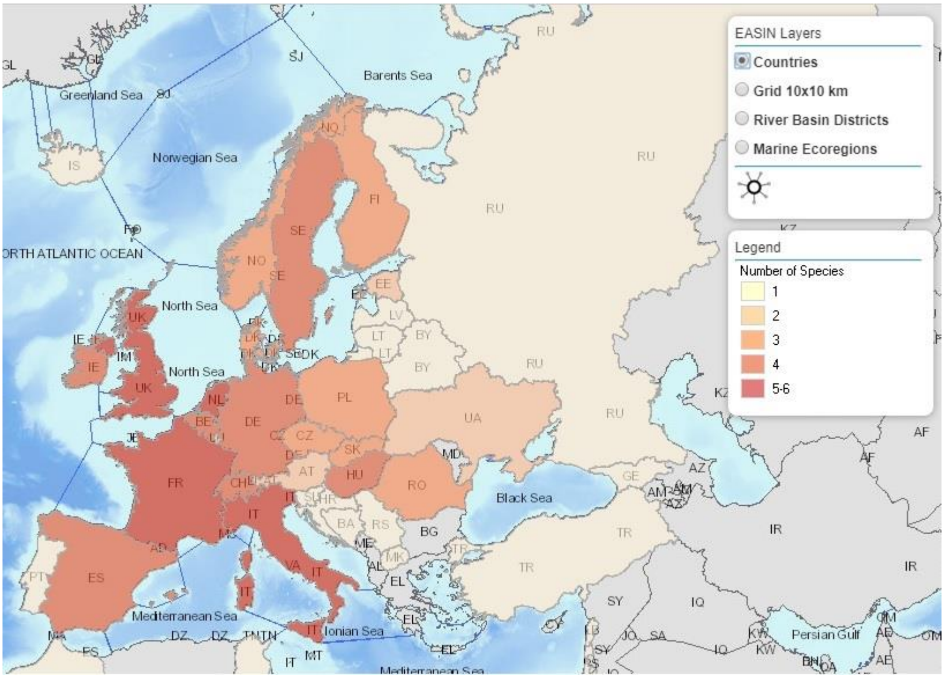

Fig. 1. Number of EU worst invasive alien plant species registered per country [19], [20].

If we look at European worst invasive plant species (Fig. 1), then France, Italy, United Kingdom and the Netherlands are of most concern, and Latvia seems not to have this priority, as there is only one registered species that is on the European 'worst invasive species' list. However, it does not mean, there should not be a national level importance on other invasive species.

For the pan-European region, 121 species are now listed as 'worst invasive' terrestrial and freshwater species [21]. If we look at number of species per 1000 km^2, then the situation differs, but here are all the invasive species (occurring in terrestrial and freshwater ecosystems), see Fig. 2.

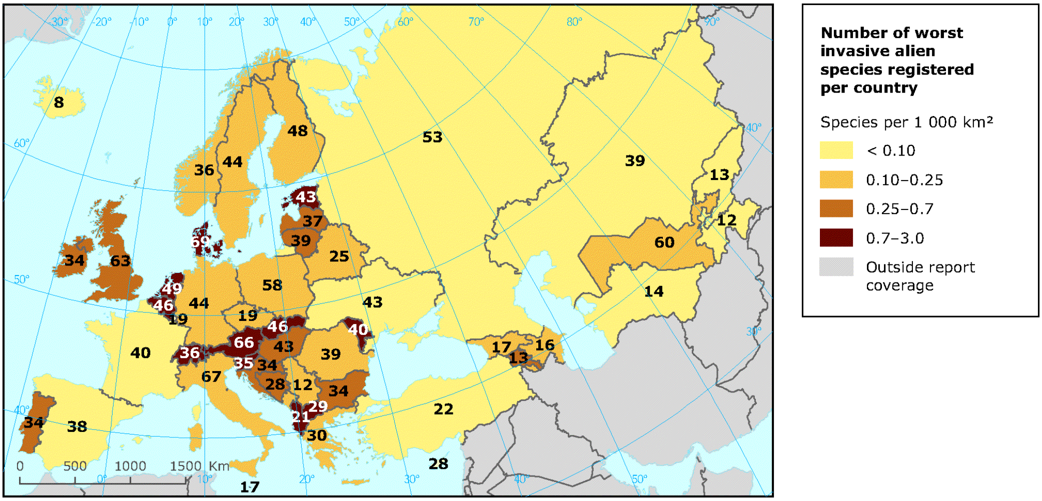

Fig. 2. Number of worst terrestrial and freshwater invasive alien species (IAS) registered per country on area (1000 km^2) [21].

The EU identifies certain plant species that pose a risk in the EU, but these species differ for each Member State. Therefore, the EU defined species are of priority, but countries should conduct research on the species present at the national level in regard to their prevalence, environmental impact and toxicology. The main direction is the integration of scientific research and the process of managing invasive plant species, thus creating the opportunity to use this biomass for the production of high added value products. This will not only enable research on methods for eradication and destruction of invasive species, but also promote research on their use and simultaneous recovery of the funds invested in the containment measures.

After assessing the possibilities of using invasive plant biomass in the national economy for the production of different products and the environmental impact of such process, the dual nature of the subject under investigation has been revealed:

- In order to preserve biodiversity, the spread of invasive plant species must be restricted;
- To consider the use of invasive plant biomass as raw material for production, the stakeholders (entrepreneurs) are mainly interested in the economic justification of the obtained product, long-term availability of the raw materials and its market potential.

The first primarily reflects the interests of nature conservation and regulatory authorities, while the latter – entrepreneur interests. In order to provide a sustainable solution, a compromise is needed between these two sides, and only then it will be possible to ensure that the population of invasive plants does not rise, and that biodiversity is not reduced, meanwhile biomass from invasive plant management measures will be used to produce products, thus gaining economic, social, environmental and climate benefits. Consequently, a major international level problem arises: how should invasive plants be managed in order not only to meet environmental requirements, but also – derive economic and social benefits?

Scientific literature already indicates the scientific potential for solving this problem, because the application of scientifically-based methods allows not only to find innovative and environmentally friendly technological solutions for the use of invasive plants in production, but also to determine the potential for commercialization, the impact on the environment and the climate throughout the product life cycle, the availability of resources and the opportunities for using alternative resources, which are very important in the case of invasive plants as a resource. Therefore, in order to find a solution for the identified problem, the aim of this project is to develop a methodology for the sustainable management of invasive plants in compliance with the bioeconomy and environmental requirements.

Invasive alien species are a major driver of biodiversity loss and should be considered and researched in the context of climate change and adaptation [22].

2. Materials and Methods

The aim is to deliver a new vision on an invasive alien plant management system. The main concern on using IAS as a potential biomass source is the risk on cultivating. There should be policy instruments in place to exclude this risk, therefore one very important aspect for product production is to find a non-invasive plant substitute biomass, to ensure sustainable production.

The main pillars of the invasive alien plant species management system can be seen in Fig. 3. The use of invasive plants for production of products opens up opportunities not only for bio-economy development and acquiring the benefits related to it, but also creates a new stock of bio-resources, without competing with agricultural crops intended for food production. At the same time, the product production should aim to find solutions that can later be applied for the use of other bioresources, thus reducing the risk of deliberate cultivation of invasive plants.

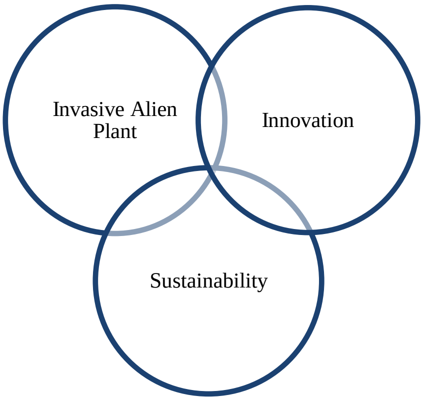

Fig. 3. Main pillars of the Invasive Alien Plant (IAP) management system.

The proposed methodology (Fig. 4) is based on the existing management plan, with an addition on new vision, where after mechanical control, invasive plant species create potential biomass for product production, however, there should be a clear assessment on biomass availability that would be economically viable, and there should also be an assessment on sustainability and possible substitution with other non-invasive plant biomass.

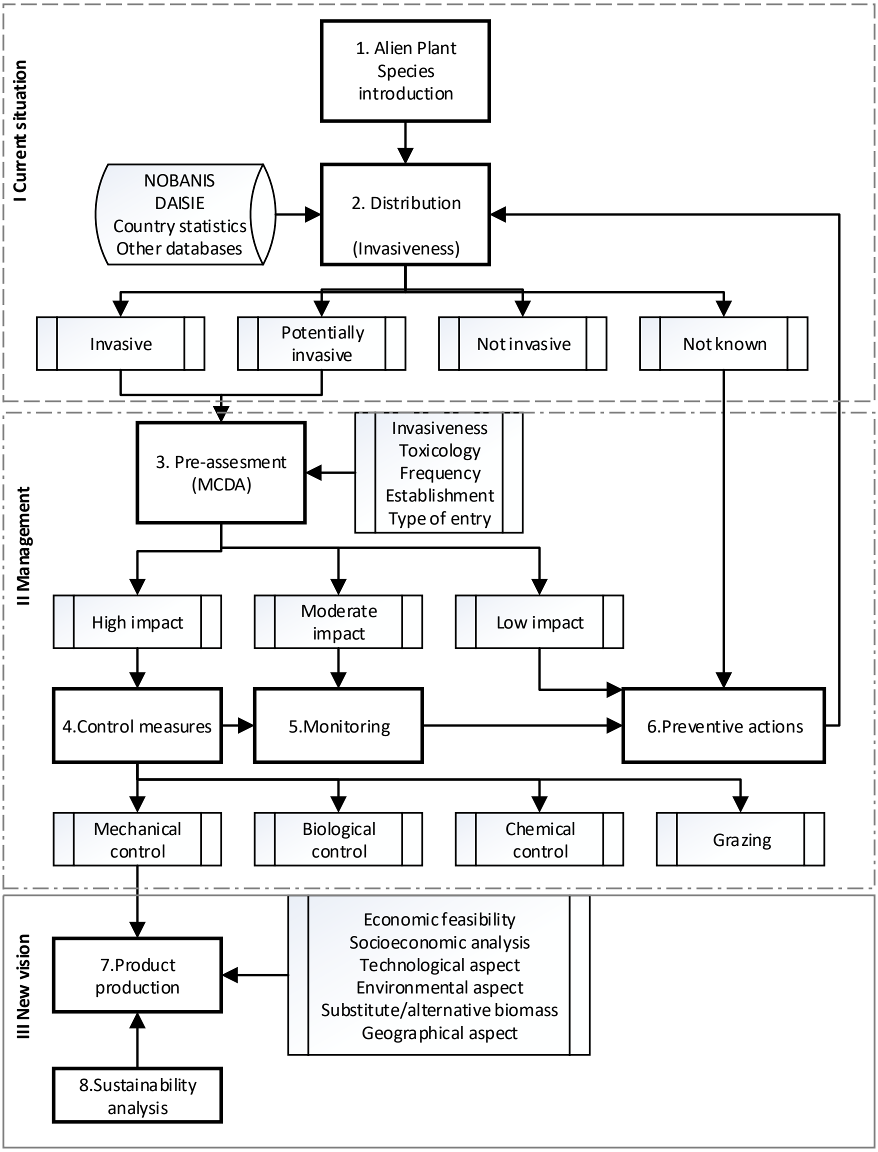

Fig. 4. New vision on invasive alien plant management system.

2.1. Current Situation

As well researched at the international and national level, there are several databases created that can be used on data selection: *DAISIE* (Delivering Alien Invasive Species Inventories for Europe) [23], *NOBANIS* (The European Network on Invasive Alien Species) [24], *GISD* (Global invasive species database) [25], *CABI* [26], *MedPAN* (network of Marine Protected Areas in the Mediterranean) [27] and *SEBI*-2010 [28] all can be found in *EASIN* species mapper [20] which offers Europe data on environment, impact, species status, taxonomy and pathways. Based on the current situation, one of the most important indicators is invasiveness, not all alien species are invasive, but for early detection and eradication, the invasive and potentially invasive species must be selected.

2.2. Management

System for IAS management differs between countries, and there are national management plans developed in each of the countries, as well as at the European level. There could be a potential multi criteria decision analysis (MCDA) in place, to create a common framework on invasive species selection on the national level. There are several researches on indicators that should be selected, but a common framework would be an essential and possible way for every country to use as pre-assessment, where priority species can be selected for further analysis. Such criteria selection is still under development in Latvia. Control measures, monitoring and preventative actions are already in place.

The MCDA method Technique of Order Preference by Similarity to the Ideal Solution (TOPSIS) was used. In this case 'ideal solution' is the species that shows priority for further assessment of impact on ecosystem services, to biodiversity, social and economic impact (high, moderate or low) in this pre-assessment. In this case, alternatives are invasive alien plant species detected in country which are invasive or potentially invasive.

TABLE 1. CRITERIA, VALUATION SCORE AND WEIGHT DETERMINATION

	Criteria, *i*	**Valuation score**	**Weight coefficient**
i_1	Toxicology	0/1	0.18
i_2	Type of entry	0/1.5/1	0.07
i_3	Establishment	0/1/2/3	0.18
i_4	Invasiveness	1/2	0.31
i_5	Frequency	1/2/3/4	0.25
		$\sum$	**1.00**

Evaluation criteria are based on available data on IAP type of entry, establishment, invasiveness, frequency and toxic impact. Eight experts were selected on determination on weights of these criteria, (Table 1) two biologists, one microbiologist and five environmental scientists. In analysis, only criteria weights were selected by experts, valuation of criteria was determined from data about IAP. Valuation ratio was selected as:

- Toxicology of the species values 0 – not toxic, 1 – toxic. Determines species harmful substances as threat to animal or human health;
- Type of entry or introduction of IAP can be characterized as intentional – 0, unintentional 1, or both – 1.5. Unintentional type of entry has the higher score, as the control measures are more difficult to implement in this case;
- Establishment or population status: established – 3 were species have formed self-

reproducing populations, not established – 1 were species have not formed self-reproducing populations and escaped – 2 escaped from captivity, gardens, agriculture, other culture, extinct and unknown – 0;

- Invasiveness: Invasive – 2 are alien species, the spreading of which threatens or damages biodiversity and related ecosystem services by occupying new habitats to the detriment of other species [29]. Potentially invasive – 1 represents a threat to biological diversity, are in neighbouring countries or boreal biogeographical region countries;
- Frequency: Rare – 1 were species observed only in certain places. Local – 2 patchy distributions, with higher abundance in certain localities. Often – 3 or common were those species which are not abundant, but are easy to find throughout the country. Very often – 4 Frequently occurring throughout the country in high abundance.

2.3. New Vision

The new vision contributes on the economic and social levels, assessment already described in previous research [9], [15], [30]–[32]. IAP as biomass for product production should be under a legal permit, to ensure the production is under elimination practices of invasive plant species, and could be as a side stream of production with the same qualities provided from another biomass. In terms of bioeconomy there should be a higher added value product, but assessment is required and it could be a multi criteria decision analysis, as presented in previous research. IAP as a biomass source could be transferred from mechanical control, as it provides IAP as waste materials.

3. RESULTS AND DISCUSSION

Results are presented by analysing the national level case of Latvia.

3.1. Current Situation

First the current situation in Latvia for invasive plant species is characterized from registered alien plant species to their invasiveness, distribution and establishment. The Sankey diagram has been chosen for flow visualization (Fig. 5).

In Latvia from 636 alien plant species, 210 are non-invasive (Fig. 5), and for 269 species there is a lack of information on invasive character, however as most of them are rarely distributed, there should not be serious concerns. Invasive and potentially invasive species should be researched more, as most of them have already established. Criteria have to be selected and both invasive and potentially invasive species should be analysed.

Invasive plant species that are evaluated as very often in distribution and are established, are: *Bellis perennis, Galinsoga parviflora, Impatiens parviflora, Bunias orientalis, Lupinus polyphyllus, Malus domestica, Sorbaria sorbifolia, Spiraea × billardii* (hybrid).

Invasive plant species that are evaluated as occurring often and established are: *Acer negundo, Amelanchier spicata, Cerasus vulgaris, Cytisus scoparius, Echinocystis lobate, Galinsoga quadriradiata, Heracleum Sosnowskyi, Hippophae rhamnoides, Impatiens glandulifera, Ligustrum vulgare, Prunus cerasifera var divaricate, Ribes nigrum cv, Ribes rubrum, Rosa rugose, Rumex confertus, Sambucus racemose, Sisymbrium loeselii, Solidago canadensis, Spiraea alba, Swida alba, Symphoricarpos albus var laevigatus, Syringa vulgaris.*

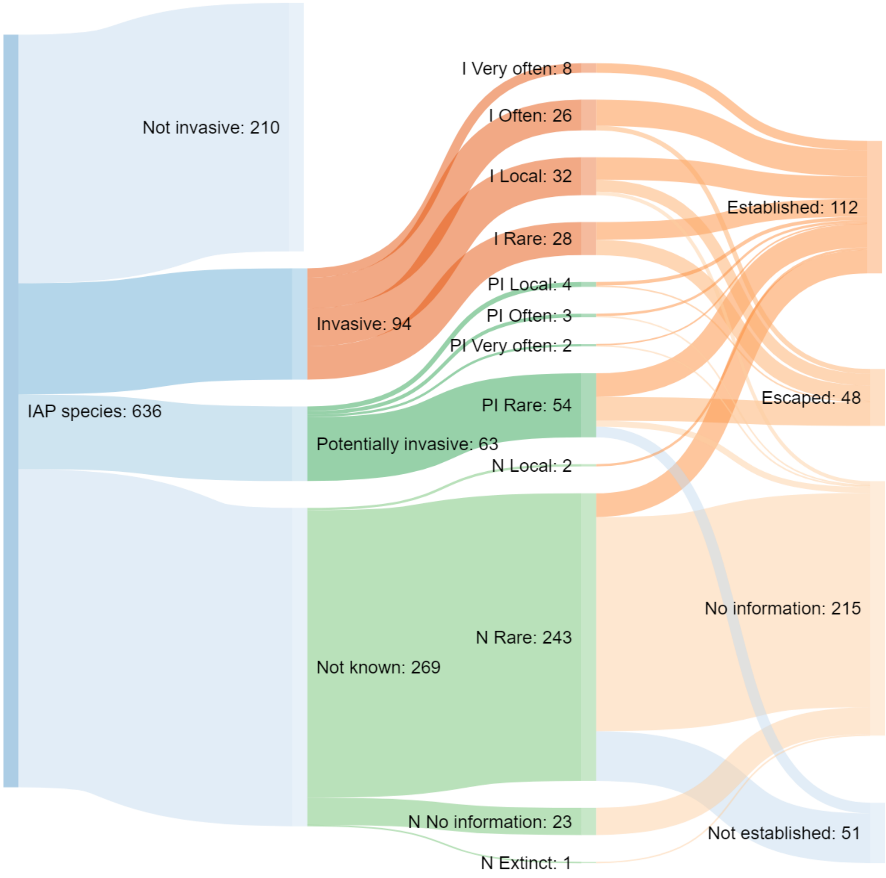

Fig. 5. Alien plant species distribution in Latvia.

Potentially invasive species that are occurring very often are *Acorus calamus* and *Elodea canadensis*.

3.2. Assessment MCDA

After alien species analysis on their invasiveness, MCDA were made on invasive and potentially invasive species, together 157 species were analysed. MCDA TOPSIS results in Fig. 6 show similarity in some ratios, meaning that there can be variation groups of species that share the same ratio.

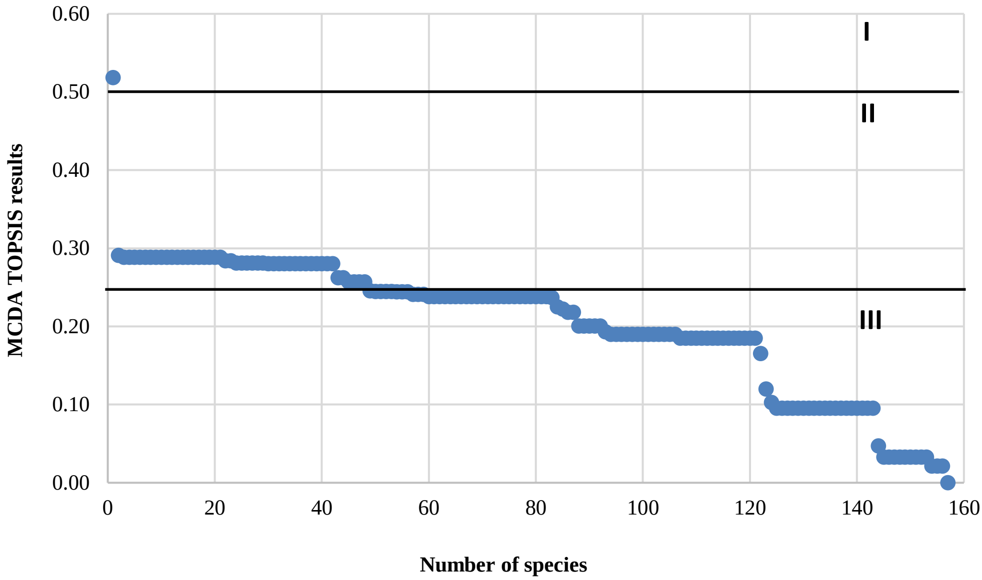

Fig. 6. MCDA-TOPSIS results on analysed IAP.

The results are divided in three levels, that could determine priority selection for further studies. At the first level, the highest score is IAP species *Heracleum Sosnowskyi* M., in this case the most decisive criterion is toxicology, because the sap of this species poses a threat to human health. There are 48 species in level II with a score above 0.25, that could also be analysed for potential monitoring and risk assessment on impact to biodiversity. Although there are a majority of species in III level, and could not be set as priority, however, there are some ratios which are very close to level II. Thus, it could be advised to look in detail at about 80 species, that show higher scores, especially that valuation score on some of the species that has ratio 0.244 was high, as they are established (score 3), invasive (score 2) and very often distributed (score 4), and intentional and unintentional type of entry (score 1.5), such species is for example *Bellis perennis*. However, species that have a ratio of 0.281 valuation score were slightly less, as they are established (score 3), invasive (score 2), often distributed (3), and intentional and unintentional type of entry (score 1.5), for example *Solidago Canadensis*. Sensitivity analyses are contained in Annex Fig. 1–5, all of the weights show sensitivity, especially toxicology and frequency.

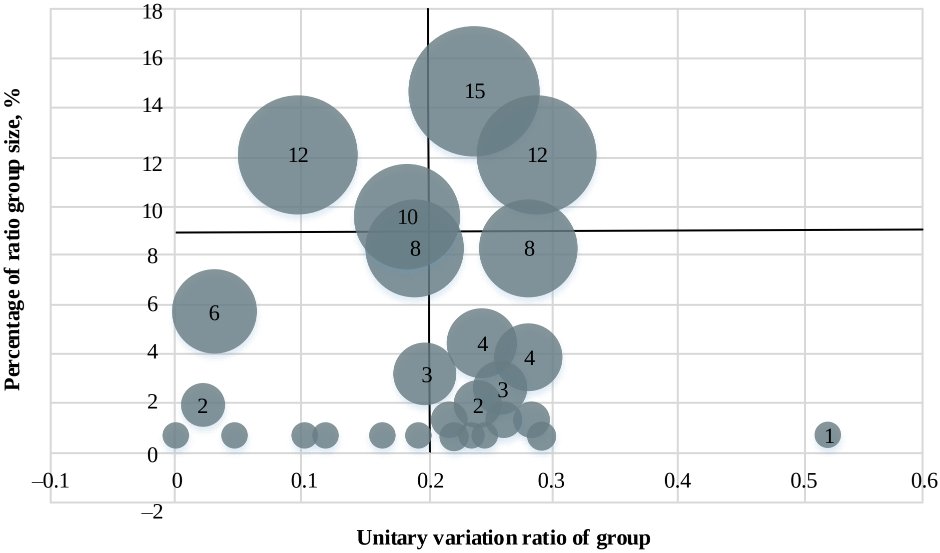

Fig. 7. MCDA TOPSIS unitary variation ratio on IAP groups.

If the results are combined in groups by ratio, the group size can be more clearly determined. If the ratio is high, that species from the entire group with that ratio should be evaluated further.

Not all of these species are seen as a threat. Invasive alien species monitoring program in Latvia is still under development, but there are nine criteria in the existing system set after which evaluate species, that should be monitored [33]:

1. Hazardous to natural habitats (criteria that is set as priority);
2. Data on the species are not derived from other existing national monitoring programs;
3. The species multiplies in the wild (effective vegetative or generative reproduction occurs);
4. Massive economically invasive species;
5. Taxon causes genetic erosion of wild species – actively crosses a wild species;
6. Recognized as being invasive in neighbouring countries;
7. The species is or has been cultivated;
8. Species distribution studies have been carried out (criterion that is set as a priority). There is evidence of the occurrence and negative impact of the species on natural habitats;
9. The species has not taken its ecological niche and shows signs of further invasion [33].

The methodology they used included yes/no compliance with the criteria and selected species were ones that corresponded to at least seven criteria, from which two were a priority criterion [33], after which these species were selected for the necessity to monitor. There is a comparison on their preference and species that are in the priority list for monitoring and the MCDA pre-assessment ratio for those species, to see if it could be used as a methodology and recommendation.

TABLE 2. INVASIVE ALIEN PLANT SPECIES IN INTERNATIONAL AND NATIONAL CONCERN

International level (EU)	National level (Latvia)		
Species in Union concern [34]	**Species in Latvia's concern** [35]	**Species in Latvia's priority list for monitoring** [33]	**MCDA pre-assessment (unitary variation ratio)**
Alternanthera philoxeroides	*Acer negundo*	*Heracleum sosnowskyi*[3]	0.518
Asclepias syriaca	*Acer pseudoplatanus*	*Acer negundo*	0.280
Baccharis halimifolia	*Amelanchier spicata*	*Amelanchier spicata*	0.281
Cabomba caroliniana[2]	*Aronia prunifolia*	*Aster salingnus*	–
Eichhornia crassipes	*Aster salignus*	*Cotoneaster lucidus*	0.288
Elodea nuttallii[2]	*Bunias orientalis*	*Echinocystis lobata*	0.281
Gunnera tinctoria	*Campylopus introflexus*	*Impatiens glandulifera*[1]	0.281
Heracleum mantegazzianum	*Cotoneaster lucidus*	*Impatiens parviflora*	0.244
Heracleum persicum[2]	*Echinocystis lobata*	*Lupinus polyphyllus*	0.241
Heracleum sosnowskyi[1]	*Elaeagnus argentea*	*Reynoutria japonica*	0.200
Hydrocotyle ranunculoides	*Elodea Canadensis*	*Reynoutria sachalinensis*	–
Impatiens glandulifera[1]	*Epilobium adenocaulon*	*Rosa rugosa*	0.281
Lagarosiphon major	*Gypsophila paniculata*	*Sambucus racemosa*	0.280
Ludwigia grandiflora	*Helianthus tuberosus*	*Solidago canadensis*	0.281
Ludwigia peploides	*Hippophaë rhamnoides*	*Solidago gigantea*	0.189
Lysichiton americanus[2]	*Impatiens glandulifera*	*Sorbaria sorbifolia*	0.244
Microstegium vimineum	*Impatiens parviflora*		
Myriophyllum aquaticum	*Lactuca tatarica*		
Myriophyllum heterophyllum	*Ligustrum vulgare*		
Parthenium hysterophorus	*Lupinus polyphyllus*		
Pennisetum setaceum	*Malus domestica*		
Persicaria perfoliata	*Parthenocissus quinquefolia*		
Pueraria lobata	*Petasites hybridus*		
	Reynoutria japonica		
	Reynoutria sachalinensis		
	Robinia pseudoacacia		
	Rosa rugose		
	Rumex confertus		
	Sambucus nigra		
	Sambucus racemose		
	Solidago Canadensis		
	Solidago gigantean		
	Sorbaria sorbifolia		

International level (EU)	National level (Latvia)		
Species in Union concern [34]	**Species in Latvia's concern** [35]	**Species in Latvia's priority list for monitoring** [33]	**MCDA pre-assessment (unitary variation ratio)**
	Spiraea chamaedryfolia		
	Swida alba		

[1]Species that is on Union concern and is already in list of management in national level or in priority list on monitoring;
[2]Species that is in boreal biogeographical region countries (Sweden, Finland, Estonia, Lithuania) and pose potential on invading Latvia;
[3]Species in regulation in Latvia.

Species in Latvia's priority list in Table 2, show that nine species of 16 are in level I and II after MCDA ratio, three species are close to level II and two are with score close to 0.2. There should be a detailed assessment on species with lower scores, or the level should be lowered to 0.2 not 0.25. Two of the species without a score are species that in this case were not selected for analysis, because they are non-invasive. In information revised for data analysis *Aster salingnus* and *Reynoutria sachalinensis* were stated as non-invasive, established and rare distributed. However, in other sources both species have been stated as invasive. In order to work with the decision analysis matrix, data on invasive plant species should be kept up to date. Overall, the method proved to work as pre-assessment.

The new system would suggest to not only use multi criteria decision analysis (MCDA); there should be potential social and economic benefit evaluation, LCA analysis on species that is on controlling measures, especially if chemical controlling method is used, as well as product production sustainability analysis.

Criteria should be unified as common framework used among EU countries. Criteria mentioned in regulation (EU) No. 1143/2014 article 5 risk assessment, should be taken into account [3]:

– Taxonomic identity, its history, and its natural and potential range;
– Reproduction and spread patterns and dynamics;
– Potential pathways of introduction and spread;
– Risk of introduction, establishment and spread in relevant biogeographical regions in current conditions and in foreseeable climate change conditions;
– Current distribution of the species, including whether the species is already present in the European Union or in neighbouring countries, and a projection of its likely future distribution;
– Impact on biodiversity and related ecosystem services, including on native species, protected sites, endangered habitats, as well as on human health, safety, and the economy;
– Potential costs of damage;
– Uses for the species and social and economic benefits deriving from those uses [3].

3.3. Management

Management system is controlled by legislation requirements and policy instruments. There should not be registered only species that are under European Union concern, but for now, this is the case. Despite the fact that 15 species are already included in the "unwanted" list for having a significant impact on ecosystems and spreading, and more species are intended to be included, only one is officially recognized as invasive (*H. Sosnowskyi* Manden) and included in the Cabinet of Ministers Regulation No. 468 [17] on the list of invasive plants.

In Estonia, the law includes 13 plant species [18], some of which are species that are included in the "unwanted species" list in Latvia, for example *Solidago Canadensis* L.

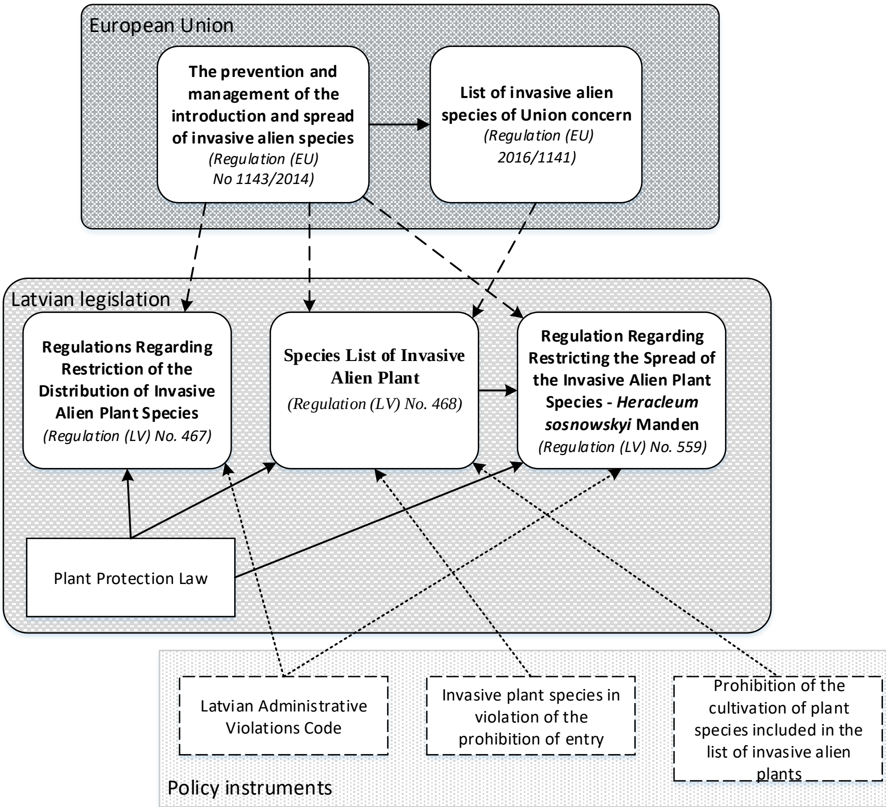

Fig. 8. Invasive alien species legislation requirements and policy instruments in Latvia.

The regulations regarding restriction of the distribution of invasive alien plant species, Fig. 8, are currently based on European Union regulations, and the IAS species of European Union concern are already under controlling measures and included in Latvian legislation. There are some policy instruments used to control the spread of one invasive alien species – *H. Sosnowskyi* Manden.

There are only sanctions as policy instruments for invasive plant species, that are in the national species list, however there could be additional policy instruments with positive reinforcement for controlling the spread, so the land owners would be motivated to address the issue, therefore get more precise data on invaded land area.

3.4. Control Measures

For this species, several methods for controlling and eradication are provided within legislation – biological, chemical, mechanical or combined control of species. The biological control used such as cattle and sheep grazing have its benefits in terms of use as fodder crop, but there are some drawbacks, that limit the use of hogweed as fodder crop. First of all, the furanocoumarins present in sap can sometimes cause burns in places that are not covered with fur (lips, nostrils, udder, eyes) [32], second hogweed gives an anise flavour in milk or meat. Grazing usually is selected in the early spring.

There are several mechanical methods for hogweed limitation – root cutting, mowing, removing umbels, mulching and soil cultivation [36]. Mechanical control is often used, but it still takes at least 3–6 years of continuous treatment (2–3 times during the growing period). It means that, for a new vision, biomass supply can be provided more than once a year, as it is for agricultural crops.

Chemical control is based on the use of herbicides (glyphosate, triclopyr, imzapyir), with glyphosate being the most used which poses risk of toxicity to fish and algae and therefore is not advisable to use near rivers or other water bodies. Pollution risk remains, as there is no information whether society respects this restriction [36].

Combined control – this method mostly combines mechanical and chemical treatment or mechanical and biological treatment.

3.5. Heracleum Sosnowskyi Manden in Latvia Monitoring Data

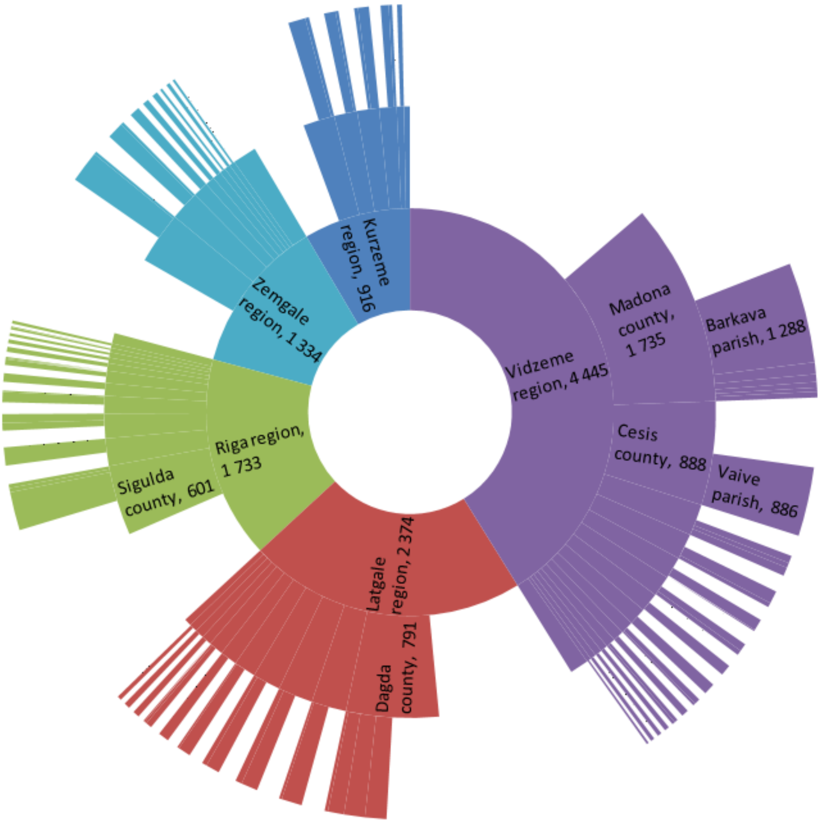

Fig. 9. *H. Sosnowskyi* distribution in Latvia.

For assessment on biomass availability for product production, distribution on invasive species and monitoring is very important, however, distribution for *H. Sosnowskyi* includes data about area (ha) in the region, see Fig. 9. There should be an assessment on biomass availability in the Vidzeme region, as it has the most potential in IAP biomass, to help controlling measures at the same time gaining social and economic benefits. Assessment should include the IAP biomass quantity after mechanical control actions. There are many options on product production on *H. Sosnowskyi* biomass, as presented in previous research [15], [31], [32]. After selection of possible product production, sustainability analysis should be the next step.

3.6. New Vision

After assessment of the existing situation in Latvia, MCDA assessment of invasive plant species, current management system and *H. Sosnowskyi* distribution in Latvia, new vision concept is presented. In previous articles validation of hogweed use as biofuel, pellets have been validated, as well as other applications have been compiled: honey, essential oil, gelling pectin, extracts, animal fodder, cardboard, with use in perfumery, pharmacology, medicine, packaging, fuel, and as food and feed [15].

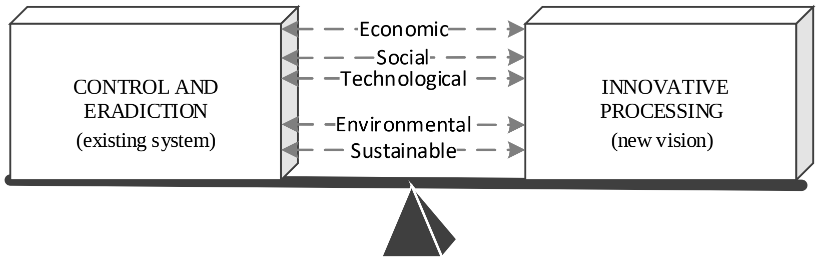

Fig. 10. New vision concept.

There has been an economic evaluation, as well as engineering, geographical, socioeconomic and environmental evaluation methodology presented [32], however future steps for validation should provide optimization between control/eradication and innovative processing of invasive plant species (Fig. 10). It means there should be found an optimum in terms of control and use, considering economic, social, technological, environmental, ecologic, geographic, socio-economic and other factors. In the bioeconomy context, one very important aspect is sustainability, therefore sustainability has to be evaluated. Products with higher added value should be a priority, but not in every case will it be feasible, therefore optimization is necessary to determine feasibility to produce products with higher added value or to determine whether energy production from invasive plant species is applicable.

3.6.1. Suitable Substitute Bio-Resources

One of the aspects that has to be considered is suitable substitute bio-resources, to ensure product production by eliminating the risk of cultivating the invasive alien plants. Invasive alien plants are mostly comparable to lignocellulosic residues, and according to their composition, the corresponding products that can be possible to obtain are selected. Product preference strongly relies on biorefinery platforms; see Fig. 11(a).

Biorefinery platforms	Cellulose
	Oils
	Lignin
	C6 sugars
	C5&C6 sugars
	Hydrogen
	Proteins
	Pulp
	Fibre
	Biogas
	Electricity
	Pyrolytic liquids

a)

Lignocellulosic biomass application	Animal feed
	Enzymes
	Biofuels
	Pulp & paper
	Fibre
	Fine chemicals
	Composites

b)

Fig. 11. a) Biorefinery platforms; b) Lignocellulosic biomass (in this case – agricultural residues) application.

Final product production bases on lignocellulosic biomass applications (Fig. 11(b)), therefore indicate suitable substitute bio-resources, that do not require cultivation to be lignocellulosic biomass as agricultural residues, such as straw, stover, cobs, stalks, bagasse etc. Lignocellulosic materials are one of the most abundant and naturally available bio-resources [37], continuous research shows the necessity to find best solutions for product production based on agricultural residues [38]–[40], that prove that available biomass substitute is freely available and secured and could convince stakeholders about long-term profitability of the technology.

4. CONCLUSIONS

In this study a new vision on IAP management system is provided. The system was analysed on the national level case of Latvia. For current situation visualization, the Sankey diagram was selected and shows flows of alien plant species, based on their invasiveness and establishment. Potentially invasive and invasive species were selected to pre-assessment done by MCDA TOPSIS on five criteria, results were compared to existing priority species set to monitoring, that determined a new level set for MCDA analysis results – if 0.2 ratios is reached, species should be assessed on criteria that determines species of national concern, if higher than 0.5 ratio is reached, species should be monitored and controlling measures should be implemented.

The results show that the new vision on the system confirms the existing system and creates complimentary steps that could improve social, economic and environmental benefits and give contribution to policy makers, land owners affected by invasive species and municipalities.

MCDA TOPSIS analysis as pre-assessment should be tested on more than one country statistics, to prove the efficiency. New vision concept does not impact the existing management system, but addresses additional section after mechanical control actions and only if available IAS biomass can be substituted with alternative plant biomass. The next steps for system validation and impact evaluation would be life cycle analysis (LCA) and sustainability analysis on product production from IAP.

ACKNOWLEDGEMENT

This research is funded by the Latvian Council of Science, project "Bioresources value model (BVM)", project No. lzp-2018/1-0426.

ANNEX

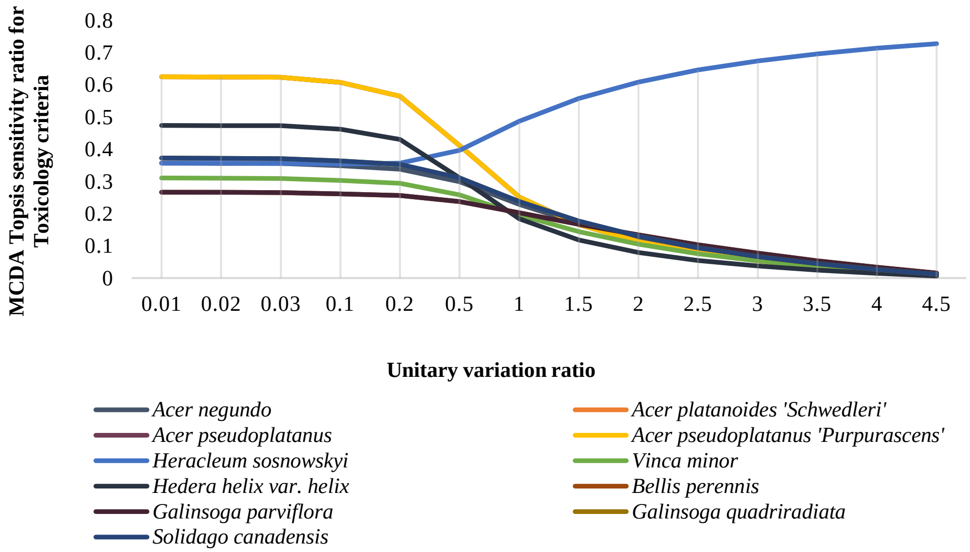

Fig. 1. MCDA Topsis sensitivity ratio for "Toxicology" criteria.

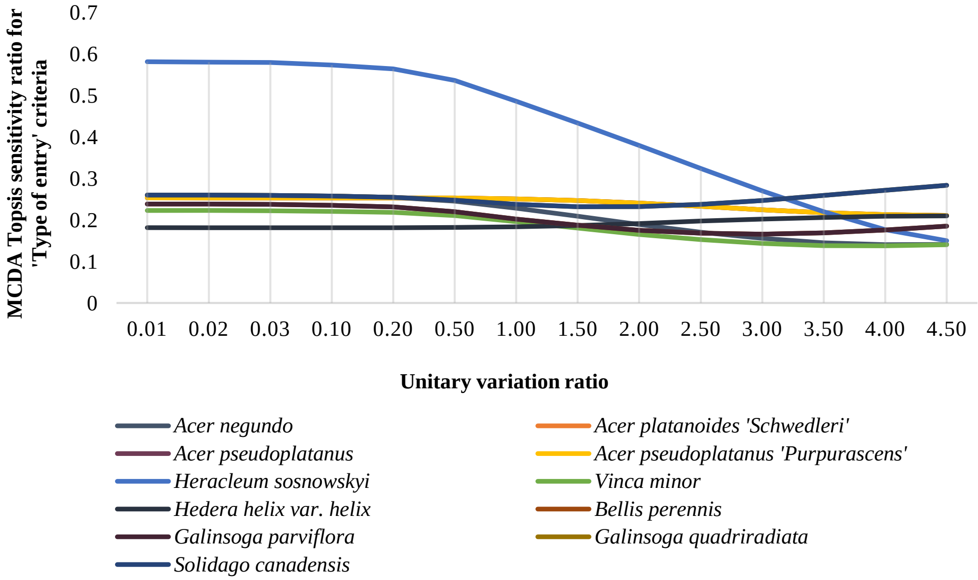

Fig. 2. MCDA Topsis sensitivity ratio for "Type of entry" criteria.

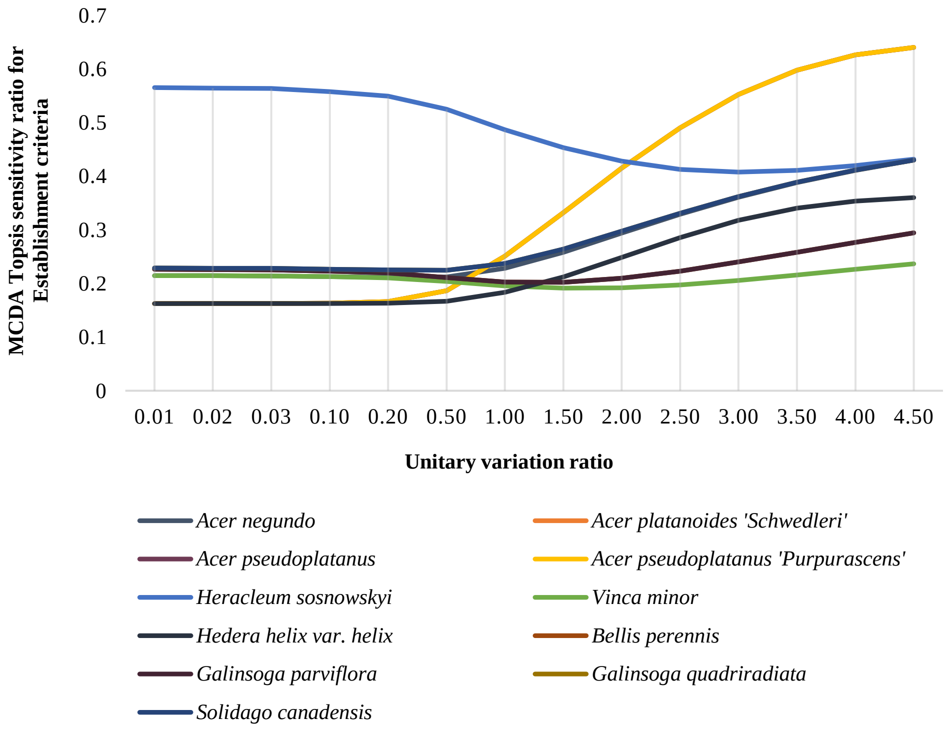

Fig. 3. MCDA Topsis sensitivity ratio for "Establishment" criteria.

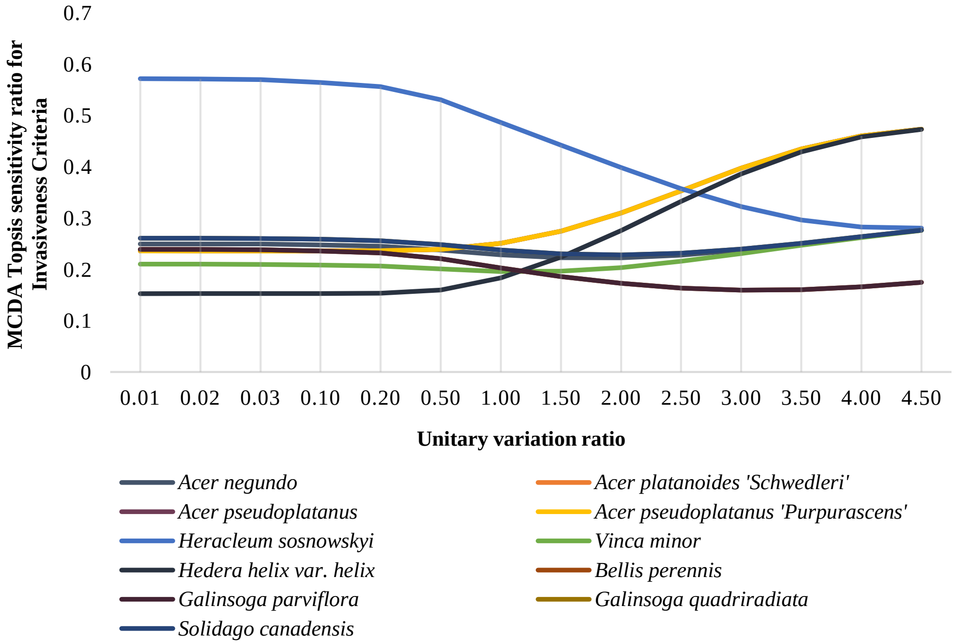

Fig. 4. MCDA Topsis sensitivity ratio for "Invasiveness" criteria.

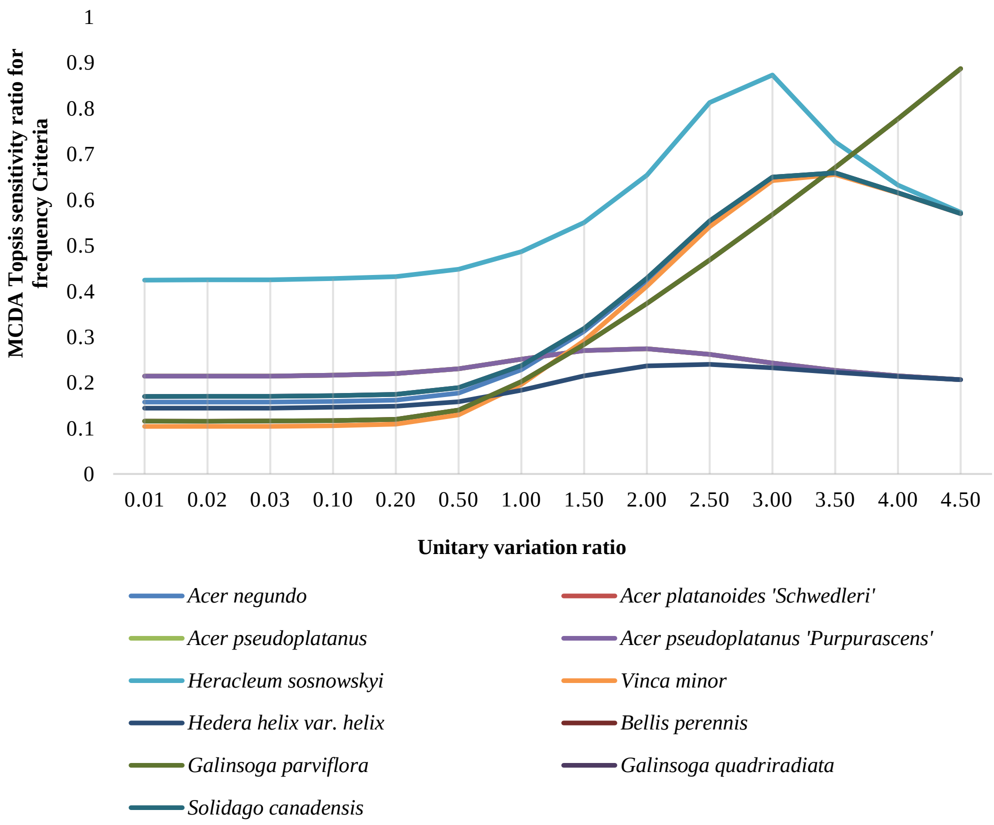

Fig. 5. MCDA Topsis sensitivity ratio for "Frequency" criteria.

REFERENCES

[1] Hulme P. E. Trade, transport and trouble: Managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 2009:46(1):10–18. doi:10.1111/j.1365-2664.2008.01600.x

[2] Kettunen M., et al. Technical support to EU strategy on invasive alien species (IAS) – Assessment of the impacts of IAS in Europe and the EU. Institute for European Environmental Policy 2008:44.

[3] Regulation (EU) No. 1143/2014 on the prevention and management of the introduction and spread of invasive alien species. *Official Journal of European Union* 2014:L317/35.

[4] Rodzkin A., Kundas S., Charnenak Y., Khroustalev B., Wichtmann W. The Assessment of Cost of Biomass from Post-Mining Peaty Lands for Pellet Fabrication. *Environmental and Climate Technologies* 2018:22(1):118–131. doi:10.2478/rtuect-2018-0008

[5] Priedniece V., Spalvins K., Ivanovs K., Pubule J., Blumberga D. Bioproducts from potatoes. A review. *Environmental and Climate Technologies* 2017:21(1):18–27. doi:10.1515/rtuect-2017-0013

[6] Zihare L., Blumberga D. Market opportunities for cellulose products from combined renewable resources. *Environmental and Climate Technologies* 2017:19(1):33–38. doi:10.1515/rtuect-2017-0003

[7] Spalvins K., Blumberga D. Production of Fish Feed and Fish Oil from Waste Biomass Using Microorganisms: Overview of Methods Analyzing Resource Availability. *Environmental and Climate Technologies* 2018:22(1):149–164. doi:10.2478/rtuect-2018-0010

[8] The Biodiversity Information System for Europe (BISE). Invasive species – Biodiversity Information system for Europe [Online]. [Accessed 3.08.2018]. Available: https://biodiversity.europa.eu/topics/invasive-species

[9] Fang J.-N., Wei Y.-A., Liu B.-N., Zhang Z.-H. Immunologically active polysaccharide from *Phragmites communis*. *Phytochemistry* 1990:29(9):3019–3021. doi:10.1016/0031-9422(90)87126-F

[10] Cui X., et al. Application of *solidago canadensis* to preparation of whitening and anti-aging cosmetic. CN103800254A, 2014.
[11] Mishra D., Joshi S., Sah S., Bisht G. Chemical composition, analgesic and antimicrobial activity of *Solidago canadensis* essential oil from India. *Journal of Basic Clinical Pharmacy* 2011:4(1):63–66.
[12] Deng Y., et al. Polyphenols, antioxidant and antimicrobial activities of leaf and bark extracts of *Solidago canadensis L. Industrial Crops and Products* 2015:74:803–809. doi:10.1016/j.indcrop.2015.06.014
[13] Zihare L., Blumberga D. Insight into bioeconomy. *Solidago canadensis* as a valid resource. Brief review. *Energy Procedia* 2017:128:275–280. doi:10.1016/j.egypro.2017.09.074
[14] Politowicz J., et al. Antimicrobial activity of essential oil and furanocoumarin fraction if three *Hearcleum* species. *Acta Pooniae Pharmaceutica* 2017:74(2):723–728.
[15] Zihare L., Gusca J., Spalvins K., Blumberga D. Priorities determination of using bioresources. Case study of Heracleum sosnowskyi. *Environmental and Climate Technologies,* In Press.
[16] Patova O. A., et al. Physicochemical and rheological properties of gelling pectin from Sosnowskyi's hogweed (*Heracleum sosnowskyi*) obtained using different pretreatment conditions. *Food Hydrocolloids* 2017:65:77–86. doi:10.1016/j.foodhyd.2016.10.042
[17] European Commission. Invasive Alien Species – Regulations, 2014 [Online]. [Accessed 3.08.2018]. Available: http://ec.europa.eu/environment/nature/invasivealien/index_en.htm
[18] European Commission. Innovating for Sustainable Growth: A Bioeconomy for Europe. 2012.
[19] European Commission. Joint Research Centre. European Alien Species Information Network (EASIN). 2019 [Online]. Available: https://easin.jrc.ec.europa.eu/.
[20] European Environment Agency. Number of species in the pan-European region listed as 'worst invasive alien species threatening biodiversity in Europe' occurring in terrestrial and freshwater ecosystems. 2012 [Online]. Available: https://www.eea.europa.eu/data-and-maps/figures/number-of-species-in-the-pan-european-region-listed-as-worst-invasive-alien-species-threatening-biodiversity-in-europe-occurring-in-terrestrial-and-freshwater-ecosystems.
[21] European Environment Agency. Invasive alien species in Europe. 2017 [Online]. Available: https://www.eea.europa.eu/data-and-maps/indicators/invasive-alien-species-in-europe/invasive-alien-species-in-europe
[22] European Environment Agency. Invasive alien species in Europe 2017[Online]. [Accessed 17.04.2019]. Available: https://www.eea.europa.eu/data-and-maps/indicators/invasive-alien-species-in-europe/invasive-alien-species-in-europe
[23] DAISIE. Delivering Alien Invasive Species Inventories for Europe [Online]. [Accessed 17.04.2019]. Available: http://www.europe-aliens.org
[24] NOBANIS. NOBANIS – European Network on Invasive Species [Online]. [Accessed 17.04.2019]. Available: https://www.nobanis.org
[25] Invasive Species Specialist group (ISSG). Global Invasive species database [Online]. [Accessed 17.04.2019]. Available: http://www.iucngisd.org/gisd
[26] CABI. Impacts of invasive species [Online]. [Accessed 17.04.2019]. Available: https://www.cabi.org/projects/controlling-invasive-species/impacts
[27] MedPAN. MedPAN is the network of Marine Protected Areas managers in the Mediterranean [Online]. [Accessed 17.04.2019]. Available: http://medpan.org/about
[28] Biodiversity Information System for Europe (BSE). SEBI – Streamlined European Biodiversity Indicators – Biodiversity Information system for Europe [Online]. [Accessed 17.04.2019]. Available: https://biodiversity.europa.eu/topics/sebi-indicators
[29] Carola O., Neacsu A. G., Arsene G-G. Invasive and Potentially Invasive Plant Species in Wetlands Area of Banat. *Research Journal of Agricultural Science* 2014:46(4):146–161.
[30] Zihare L., Blumberga D. Insight into Bioeconomy. *Solidago canadensis* as a valid resource. Brief review. *Energy Procedia* 2017:128:275–280. doi:10.1016/j.egypro.2017.09.074
[31] Zihare L., Soloha R., Blumberga D. Potential use of invasive plant species as solid biofuel by using binders. *Agronomy Research* 2018:16(3):923–935. doi:10.15159/AR.18.102
[32] Zihare L., Blumberga D. Invasive Species Application in Bioeconomy. Case Study *Heracleum sosnowskyi* Manden in Latvia. *Energy Procedia* 2017:113:238–243. doi:10.1016/j.egypro.2017.04.060
[33] Bunder P., et al. Invasive alien species monitoring program development 2015.
[34] European Commission. List of Invasive Alien Species of Union concern [Online]. [Accessed 23.04.2019]. Available: http://ec.europa.eu/environment/nature/invasivealien/list/index_en.htm
[35] The Nature Conservation Agency. Invasive species [Online]. [Accessed 23.04.2019]. Available: https://www.daba.gov.lv/public/lat/dabas_aizsardzibas_plani/dati1/invazivas_sugas
[36] CABI. Heracleum sosnowskyi (*Sosnowskyi's hogweed*) [Online]. [Accessed 19.07.2019]. Available: https://www.cabi.org/isc/datasheet/108958
[37] Bilal M., et al. Biotransformation of lignocellulosic materials into value-added products − A review. *International Journal of Biological macromolecules* 2017:98:447–58. doi:10.1016/j.ijbiomac.2017.01.133
[38] Solle M. A., et al. Value-added composite bioproducts reinforced with regionally significant agricultural residues. *Composites Part A: Applied Science and Manufacturing* 2019:124:105441. doi:10.1016/j.compositesa.2019.05.009

[39] Nasir M., et al. Recent development in binderless fiber-board fabrication from agricultural residues: A review. *Construction and Building Materials* 2019:211:502–516. doi:10.1016/j.conbuildmat.2019.03.279

[40] Zihare L., Spalvins K., Blumberga D. Multi criteria analysis for products derived from agro-industrial by-products. *Energy Procedia* 2018:147:452–457. doi:10.1016/j.egypro.2018.07.045