Life cycle assessment (LCA) of potato production

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Abstract. The paper analyses the detailed structure of the environmental footprint of technologies used for potato production on plantations covering areas of various sizes. The research was conducted for potato cultivation in Lesser Poland. In order to determine the environmental impact with the LCA method, the SimaPro application was used, ver. 8.1.0.60. The "cradle-to-gate" approach was adopted, taking into account the type of technological practices, as well as machines, duration of their operation, number of seed potatoes, fertilisers, pesticides, used fuel and water. The final results were referred to the area of cultivation (1 ha). It was, for instance, found that one of the greatest impact factors of potato cultivation affecting the natural environment is the use of seed potatoes and relatively high consumption of diesel.

1 Introduction

Global food systems depend on outlays of resources and energy requisite for the production and supply of food. This consumption is related to significant environmental changes. Fertilisers, pesticides and energy required for crop cultivation are manufactured in quantities depleting natural resources and placing enormous burden on the environment [11, 12]. The rising popularity of fertilisers substantially contributes to emissions of greenhouse gases and generates emissions of NH₃ or N₂O; it also pollutes water [17]. The increased frequency with which intense food production methods are utilised has been accelerating the depletion of natural resources and climate change [9]. Aside from such practices as may typically be related to cultivation, further post-harvest processing, storage, cooling and packing also significantly influence the natural environment [5, 18]. Unfortunately, a great portion of yield harvested is damaged while in storage [6, 7], which only makes the burden on the environment arising from cultivation pointless.

The agricultural sector has been identified as one which adds to the burden on the environment to a great extent, including acidification, eutrophication, toxicity and changes of the climate [2, 3]. On account of the above correlations between agricultural production and the natural environment, food systems are the main focus of the 2030 Agenda for Sustainable Development, a global obligation to eliminate poverty and hunger, with the simultaneous reduction of environmental and socio-economic effects [15].

The (*Solanum tuberosum* L.) potato is one of the most popular edible plants in the world. This tuberous crop serves an important role in human and animal nutrition and is cultivated under various climatic conditions. In fact, it is the fourth most popular crop, after wheat, rice and maize [16]; furthermore, the plant is characterised by a high nutritional and energy value per unit of area [19]. Due to the relatively high requirements for fertilisation and

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protection, it is only to be expected that potato cultivation exerts a significant impact on the environment. The issues of the environmental footprint of potato cultivation have been addressed by, for instance, [10, 16]; however, there is still a deficiency in up-to-date research results within this scope. The question which seems especially important is: which factors related to potato cultivation affect the environment the most? Yet another interesting question may be: does the area covered by a potato plantation significantly affect the unit environmental footprint?

At present, one of the most frequently used methods for evaluating the environmental footprint is the Life Cycle Assessment (LCA) [14]. It is recommended by ISO 14040. The LCA also benefits the agricultural production sector [13]. This approach is a tool for the comprehensive assessment of said environmental impact at all stages of production processes. Its guidelines and rules are contained in ISO standards related to environmental management (ISO 14040), introduced by the International Organisation for Standardisation (ISO) [1]. The present paper discusses the LCA method in the evaluation of factors affecting the environmental burden attributable to potato cultivation.

2 Aim, scope, subject and methodology of research

The purpose of this paper was the comparative analysis of factors and structure of the environmental impact of potato cultivation on plantations covering areas of various sizes.

In order to determine the factors and structure of the environmental impact, the Life Cycle Assessment (LCA) method and SimaPro application ver. 8.1.0.60 were used. Further, the environmental impact assessment method ReCiPe Endpoint was applied. The Endpoint indicators show the impact on the environment in three various aspects, namely: 1) effect on human health, 2) biodiversity, ecosystem and 3) resource scarcity. The environmental impact was calculated in numerical values referred to as eco-indicators (Pt), commonly used in the LCA methodology.

The subject and methodology of research were described in a separate paper [8].

3 Research results

Tables 1 and 2 contain the total environmental impact calculated separately as resulting from the use of very production machines (P) and use of very materials (M), such as: seed potatoes, fertilisers, pesticides, fuel and water. As can be observed, the use of machinery, for the most part, affects the environment in the case of such practices as: harvest (Pt=38.77), transport (Pt=36.93 in Group 1 and 24.94 in Group 2) and soil preparation (Pt=29.36). Meanwhile, the consumption of materials for planting is Pt=86.35 in Group 1 and 85.74 in Group 2, and for mineral fertilisation – Pt=18.87 in Group 1 and 30.31 in Group 2. In both groups, the greatest environmental burden can be observed for such categories as the Human Health and Resources; the only exception is planting, where the use of seed potatoes also affects the Ecosystems to a great extent (Pt = 31.55 and 31.50).

Table 1. Environmental impact structure in Group 1

Damage category		Environmental impact			
		Total	Human Health	Ecosystems	Resources
		Pt	Pt	Pt	Pt
Soil preparation	P	29,36	12,99	5,68	10,69
	M	4,95	0,68	0,43	3,84

Mineral fertilisation	P	3,06	1,36	0,58	1,12
	M	18,87	7,53	3,35	7,99
Manure fertilisation	P	14,87	6,45	2,90	5,52
	M	2,44	0,34	0,21	1,89
Sowing	P	7,97	3,31	1,69	2,97
	M	86,35	31,84	31,55	22,95
Ridging of potatoes	P	6,09	2,54	1,33	2,22
	M	3,51	0,48	0,31	2,72
Chemical protection of plants	P	5,95	2,53	1,21	2,22
	M	6,68	1,91	0,64	4,14
Harvesting	P	38,77	16,26	7,78	14,73
	M	5,64	0,78	0,49	4,37
Transport	P	36,93	15,54	7,10	14,29
	M	5,49	0,76	0,48	4,25

Table 2. Environmental impact structure in Group 2

Damage category		Environmental impact			
		Total	Human Health	Ecosystems	Resources
		Pt	Pt	Pt	Pt
Soil preparation	P	29,36	12,99	5,68	10,69
	M	4,27	0,59	0,37	3,31
Mineral fertilisation	P	3,06	1,36	0,58	1,12
	M	30,31	12,90	5,75	11,65
Manure fertilisation	P	14,87	6,45	2,90	5,52
	M	1,83	0,25	0,16	1,42
Sowing	P	7,97	3,31	1,69	2,97
	M	85,74	31,76	31,50	22,49
Ridging of potatoes	P	6,09	2,54	1,33	2,22
	M	2,74	0,38	0,24	2,13
Chemical protection of plants	P	7,44	3,16	1,51	2,77
	M	7,66	2,28	0,83	4,55
Harvesting	P	38,77	16,26	7,78	14,73
	M	5,18	0,71	0,45	4,01
Transport	P	24,94	10,49	4,79	9,65
	M	3,66	0,50	0,32	2,83

Figures 1 and 2 show the environmental impact structure for machinery and materials in both area groups. As for the impact of machinery, the higher environmental impact (Pt=143.0) was observed in Group 1; it is mainly caused by the greater utilisation of means of transport, related to the transfer of manure in larger quantities when compared to Group 2 (Pt=132.5). Meanwhile, the analysis of the environmental impact of used materials (Fig. 2) indicates a slightly higher level in Group 2 (Pt=141.4), which is attributable to the higher consumption of mineral fertilisers when compared to Group 1 (Pt=133.90). Due to the varied calculation methodology and system boundaries adopted for the research, it is difficult to refer the results yielded to the source literature which also contains data on potatoes. In comparison, the environmental footprint of lettuce cultivation according to the same methodology and analogous system boundaries is approx. 200 Pt [4].

Fig. 1. Environmental impact structure of machinery in both area groups

Fig. 2. Environmental impact structure of materials in both area groups

4 Conclusion

Based on the analysis of the research results, it has been concluded that:

1. The environmental impact of production machinery is higher in Group 1; one of the factors contributing to its high level is transport; therefore, a very important aspect

which might reduce the environmental footprint is the location of the plantation relatively near the warehouses and storage buildings.

2. The environmental impact of the materials used for cultivation is higher in Group 2; its main factor is planting, related to the use of a great number of seed potatoes, which underlines the importance of the sufficient quality and quantity of the material intended for planting.

3. The comparison of the environmental footprint of used fertilisers clearly indicates organic fertilisers, that is to say manure, as more friendly to the natural environment. Even with a relatively large amount of manure (3,390 kg ha⁻¹), as on the plantations of Group 1, its environmental footprint is barely 1.8%, whereas mineral fertilisers, which compensate for missing ingredients, constitute 14% of the entire environmental impact of materials for potato production.

4. The reduction of the environmental impact of agricultural cultivation entails practices aimed at increasing areas of crop plantations, such as the consolidation and division of arable land

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