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An assessment of biomass production potential in Poland and impacts on food security

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Abstract

In this paper, an assessment of biomass production potential in Poland in 2020 and 2030 was calculated. Two scenarios were defined, representing constraining attitudes towards available agricultural land, production system, diet change and population decrease. They are named as a baseline constant scenario (BCS) and future variable scenario (FVC). In BCS scenario, we assumed constant crop yields, consumption per capita, decrease of land use for no agricultural purposes, food reserves and loses, and no change of the current policy. Only a decline in population occurred. The FVC is a scenario were both crops yields and consumptions per capita are changed, based on linear trends. Other input data and changes are the same like in BSC scenario. In our study, in both scenarios self–sufficiency for production is assumed. Therefore, there is an absence of international trade in food and feed in the calculation. Based on our analysis, areas of agricultural land in Poland could possibly be made available for future biomass production for energy use. The accessible land areas increased when the potential food production became higher in comparison with the food requirements (dependent on a decreasing population and mean consumption pattern). This study shows that 79% of the present agricultural land area is needed for food production in 2020 and 73% in 2030 respectively, if the FVC is applied. The remaining 21% in 2020 and 27% in 2030 can be used for other purposes, such as biomass production. If the BCS is applied, then a smaller area is available for biomass production, e.g. 14% and 17% in 2020 and 2030, respectively.

Key words: Biomass production, food security, grain equivalents, population, production, scenarios

Introduction

The European Union (EU) has set goals for renewable energy for 2020. According to the EU Directive 2009/28/EC, EU member states should increase the use of renewable energy to 20% for the final energy consumption and 10% renewable energy in the transport sector by 2020. To meet these targets the production of crops used for biofuels have to increase. Biofuels, mainly ethanol and biodiesel, are produced from a number of agricultural crops that are also important for providing food and feed.

Land is an essential resource for food production. The factors influencing the changes of this resource are population growth, economic development and environmental changes. All these factors change over times. Over the last decade, Europe reported a stagnated demand for food crops caused by an aging population and increase in crop yields[16]. Based on different assumptions describing a requirement of the land for food production, many studies have been conducted [1, 10, 11, 18-22, 26]. The general conclusion from these studies indicates that in the EU is more than enough agricultural land available to meet these needs. The surplus of the land could be used for other purposes such as biomass production for energy, which is considered to be climate neutral.

Emission of the carbon dioxide (CO_2) is caused by using fossil fuels for energy. This emission may be reduced by using biomass as the energy sources. The CO_2 emitted from biomass usage as an energy source, equals the CO_2 taken up in the photosynthetic process, which results in a cancellation of any extra CO_2 emissions to atmosphere.

Until now in Poland, agricultural biomass for bioenergy has been derived from conventional rotation food crops such as maize, wheat, barley, sugar beet and rape. The production requirements of these crops, when used for bioenergy, are similar to those used for food and fodder. The cultivation of these crops offers a little opportunity to reduce fertiliser and pesticide inputs compared to their management for food [25].

The production of food with animal protein requires plant biomass, part of which consists of grain that could have been used as a food. Animals consume almost 40% of all grain [19]. According to USDA, presently over 35% of the cereal produced is fed to livestock. Biomass used as a renewable energy source competes with food crops for land. Therefore, an estimation of biofuel potential is the important task. Some studies have noted that a conflict with food production could be diminished by the use of marginal, idle and degraded land for biofuel production [16]. The aims of this study were: (i) to estimate the Polish potential of food production at present, in 2020 and 2030; (ii) to assess the demand for the food in 2020 and 2030 and (iii) to determine the possibility for biofuel production from surplus agricultural lands in 2020 and 2030.

Materials and Methods

In this study, we followed the method developed by Penning de Vires *et al.* [19] where data on food consumption are compared with data on production.

Determination of food demand: The Polish food requirement is estimated based on a future projection of the population (2020 and 2030) with one kind of diet. The population data was taken from Central Statistical Office [4] databases for the present (2010) and for the future (2020 and 2030). In Poland, the projected population will be decreasing, which is opposite to the global trend (Table 1). In 2020, the number of people will be about 0.7% lower than in 2010, and decline will be continued to 1% in 2030.

Table 1. Population size (in 10^3 people) in year 2010 and estimates for a years 2020 and 2030.

2010	2020	2030
38.092	37.830	36.796

Source: Demographic yearbook of Poland[4].

Consumption: The diet was calculated based on the current consumption pattern, which includes the average intake of the years 2008-2010 the per capita in Poland (Table 2).

To make the diet comparable, all food products were converted to grain equivalents (GE). Penning de Vires *et al.* [19] defined GE in the consumption process, as the amount of cereal needed for the food consumed, plus “opportunity cost” to grow food that cannot be produced via grain. The conversion of different products to GE gives a possibility to compare their values in food.

The minimum caloric intake for adult is about 10 MJ per day, and this has not changed over the years. Energy in the diet should consist of at least 10% of high-quality protein, 15% from fats and oils and 55-75% from carbohydrate [9]. The diet is composed of plant, dairy and meat products. Assuming that these various components are involved in the diet, there are three types of diets: a vegetarian, a moderate and an affluent diet. The daily amount required per person is 1.3, 2.4 and 4.2 kg (dry matter) of GE for vegetarian, moderate and affluent diet, respectively [15]. The basic caloric intake is the same for all diets. However, a content of the protein increases from vegetarian to affluent diet. In the vegetarian diet, protein derived from plant origins, but for the moderate and affluent diet either from plant or animal origins. Increased participation of protein from animal origins in the affluent diet raises daily energy intake to 11.5 MJ. In Poland, an average daily consumption is around 4.4 kg GE (Table 2) like in the affluent diet. Therefore, in our research, we will consider the affluent diet.

By multiplying the population size in 2010 by the annual consumption per capita, we thereby receive the amount of food consumed in Poland. In our research, we assumed that a country should have a nutrition reserve for 60 days, and food losses are set at 20% of food consumption. A summary of these values and consumption data gave us the yearly food requirement for Poland. Fig. 1 provides an overview of steps in calculation of surplus of agricultural land available for biomass production.

Food losses occur through the food system that starts with farm production and ends when the food is consumed. The largest sources of losses are in the last step of the food system, at the final consumptions [14]. In our calculations for a food chain between the production and consumption, we assumed unavoidable crop losses at 20% of food demand. According to food balance spread sheets of CSO wastes and losses at the producers’ and turnovers, are at 8% of the domestic production [5]. This figure corresponds to annual losses of 115 kg of food per capita. An analysis of FAO’s food balance sheets presents food waste in Europe and North America on the level 95-115 kg per capita [9]. It is the edible amount of food available for human consumption but not consumed. Food service institutions in Sweden estimated food losses at 25% [8]. This number indicates only the losses after delivering food to the service institution. In 2008, in the USA, food losses at the retail and consumer level per capita were estimated at 10 and 19% of food supply, respectively [3]. Nonhebel [17] refers the total food losses at the level of 30%. The same quantity is determined by Wirsenius *et al*. [26] in many affluent countries (Finland, Spain). Food wastage is usually higher in countries with higher income per capita. In our study, we assumed lower losses of food at consumer level, e.g. 12% but total at 20%. It results from the fact that the inhabitants of Poland consume less processed foods and the Gross Domestic Product (GDP) per capita is lower compared to the previously referred countries.

Food production contrary to food requirement: The actual production data were taken from the CSO production database [5], converted to GE and summarised to show the production potential in Poland. The further stage was a calculation of production per ha of agricultural land in good agricultural condition. The term agricultural land in a good agricultural condition includes sown areas, fallow land, permanent crops, kitchen gardens, permanent meadows and pastures. The differences in the values of potential production and the food requirement determined the surplus of

Table 2. Per-capita consumption of selected foodstuffs (in kg), mean and standard deviations. Conversion factors to grain equivalent were taken from Luyten[15] .

Products	1990	2000	2005	2008	2009	2010	Mean 2008-2010	CF (kg GE^{-1}kg product)	GE (g d^{-1})
Cereals in terms of processed products	115.0	120.0	119.0	112.0	111.0	110.0	111±1.0	0.7	218
Potatoes	144.0	134.0	126.0	118.0	117.0	112.0	116±3.2	0.4	130
Vegetables	119.0	121.0	110.0	115.0	116.0	108.0	113±4.4	1	317
Fruits	29.0	51.6	54.1	55.0	55.5	45.5	52±5.6	2	292
Beef	16.4	7.1	3.9	3.8	3.6	2.4	3.3±0.8	11.1	102
Pork	37.7	39.0	39.0	42.7	42.4	42.6	42.6±0.2	6.3	753
Poultry	7.6	14.7	23.4	24.1	24.0	24.8	24.3±0.4	9.5	648
Butter	7.8	4.2	4.2	4.3	4.7	4.4	100.5*±4.7	1.5	423
Cow’s milk	242.0	193.0	173.0	179.0	182.0	189.0	187.3**±4.9	1.5	813
Hen eggs	10.6	10.5	12.0	11.4	10.6	10.7	11.5±0.1	5.3	171
Sugar	44.2	41.6	40.1	38.4	38.8	40.3	39.2±1	3	330
Veg-oil				19	20	21	20±1	3	169
Total									4367

*1 kg butter = 22.5 kg milk, **1 kg milk = 1.029 l milk. Source: Statistical yearbook of agriculture [5]

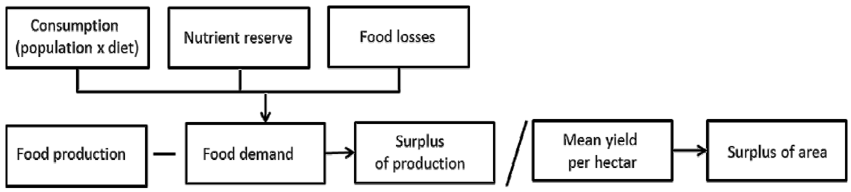

Figure 1. Flow chart illustrating the sequence of steps in the calculation of surplus of agricultural land.

food production. This value divided by the current production per ha gave us an excess of agricultural land that could be used for purposes other than food production. Similarly, the surpluses of lands for 2020 and 2030 were calculated.

In literature, the surplus of food is described by the self-sufficiency ratio [19, 27]. This ratio defines the potential food production and food requirement. Some researches assumed self-sufficiency ratio of two due to overcome yearly variation of production and losses on transportation [27]. However, the ratio may be reduced when food processing and storage are implemented, additionally, when transportation is organised efficiently. Bender [2] stated that increasing the efficiency in the food system is one of the most important issues for food security in the future and recommends further analysis of the determinants for food system efficiency. The higher self-sufficiency ratio would result in the possibility for allocation more land to other purposes than food production.

The scenarios: In our study, two scenarios were defined, representing constraining attitudes towards available agricultural land, production system, diet change and population decrease. They are named as a baseline constant scenario (BCS) and future variable scenario (FVC). An excel spread sheet modelling was used for calculation.

The baseline constant scenario (BCS): The present arable land in good agricultural condition is calculated at 14.54 Mha, based on CSO [5]. Between 2020 and 2030, crop land will decrease because of use land for building, infrastructure and afforestation. Each year 4.2 thousand ha of farm land is allocated for non-agricultural purposes. This number is based on average CSO data from 2000-2010 according to existing legal regulation on the protection of agricultural and forest land [5]. According to an adaptation of the "National Programme for Augmentation of Forest Cover," by 2020, 56 thousand ha of agricultural land will be forested and will be will be not available for agriculture. In our calculation, we assume that these changes will be continued to 2030 at the same pace. Crops, consumption patterns, food reserves and losses, in 2020 and 2030, will remain at the 2010 level. Based on CSO forecast, in 2020 and 2030 population size will change [4]. The BCS scenario assumes "business as usual" without changes of the current policy. That applies particularly for the Common Agricultural Policy (CAP). In our study, self–sufficiency for production is assumed. Therefore, there is an absence of international trade in food and feed in the calculation.

The future variable scenario (FVC): The future variable scenario is a scenario where both crops yields and consumptions per capita are changed, based on linear trends. The trends are broadly based on statistical data from CSO [5]. In 2004, Poland joined the EU and CAP had an influence on agricultural production. In the analysed period, there were upward trends in the production of four major cereals, rapeseeds, vegetables, fruits, beef, poultry, milk and eggs. This was due to agricultural production shifting to being more efficient by access to capital for modernisation, up-scaling production, using new varieties of plant adapted to climate changes and higher external input (mechanised operations, chemical fertilisers, pesticides). This increment is expected to be continued. However, in the reported period, production of potato, sugar beet and livestock decreased significantly. The quantity of production depends on the diet. In last six years (2004-2010), the consumption of vegetables, fruits, poultry, pork, milk and milk products has increased. The opposite trends were recorded for cereals, potato, sugar, eggs and beef. Other input data and changes are the same like in the BSC scenario (trends for the development of population, reduction of land use for agricultural purposes, food reserves and losses).

Results and Discussion

A summary of the simulated food requirements for both scenarios is given in Table 3. In the BCS scenario, food demand shows a downward trend. In 2020, a need for food will be lower by 0.7% compared to 2010. However, in 2030, a reduction reaches the level of 3.5%. It is a consequence of a decline in the population. The opposite trend is recorded for the FVS scenario. In 2020 and 2030, food requirement will increase by 9.6 and 16.4%, respectively, compared to today. In FVS, future requirements for food are assessed and based on linear trends of consumption per capita. The highest annual increment is predicted in the consumption of vegetables and fruits by 1.5 and 0.7%, respectively. In recent years, the inhabitants have started to eat more fruits and vegetables instead of potatoes and cereals. Therefore, a decrease in the consumption of cereals and potatoes was recorded by 1.9 and 2.3%, respectively. Recently there has been an increased intake of milk, and this tendency will be continued in the future. Milk is consumed in various forms. In our research, we assume that beef consumption, in 2020 and 2030, will be the at same level as in 2010, i.e. 3.3 kg yearly per capita, which means the end of a decline of intake. In 1990 and 2000, the mean annual consumption of beef was recorded at 16.4 and 7.1 kg per capita, respectively. Beef consumption has dropped dramatically in recent years. It was due to 'inter alia' increase of prices, drop in production, bovine spongiform encephalopathy diseases (BSE) and a diet change. The inhabitants of Poland have changed the consumption from ruminant meat to pork and poultry. This is consistent with a tendency taking place in high income regions [26]. In the last decade, in the North America and Western Europe, the total meat

Table 3. Food requirement for affluent diet and the population size in 2010, 2020 and 2030 from three scenarios express in GE (10^6 kg dry mater per year).

Year	Scenario	
	BCS	FVS
2010	80.94	80.94
2020	80.38	88.76
2030	78.19	94.29

consumption per capita has increased by 0.5% annually [26]. In our study, based on statistical data, we assume an annual growth in the consumption of pork and poultry to be 0.6 and 0.2%, respectively.

According to CSO [5], in 2010 food production was calculated at 93.76 Gkg GE (Table 4). This amount represents the total food crops harvested, and meat produced. Cereal and cow's milk had the highest share in production express in GE. A slightly smaller proportion was recorded for poultry and pork. Production of potato and beef accounted for the smallest share in total production. The produced food ensured the demand with affluent diet. In BCS, food potential is the same in future years because we assumed that production will be at 2010 level. Table 5 presents the average yields, which are rather low as compared with yields obtained in the Netherlands. In Poland, the total number of farms is above 2 million [12]. The average value of annual production of 1.25 million agricultural holdings is lower than 2 thousand Euro. The yields and crops from those farms are very low. However, their production had an influence on the average data reported by CSO [5]. For example, the average yield of cereal recorded in CSO database is 3.4 Mg ha^{-1} whereas in Farm Accountancy Data Network (FADN) database, it is 5 Mg ha^{-1} [12]. In last few years', yields in small farms have not increased despite receiving subsidies under the CAP, and in some even decreased. We do not expect that this will change in the future. However, after 2004 in large farms, yields and crops increased. It was a result of input funds from the EU. We assume that this trend will be continued, but there are uncertainties as to for how long. The output growth of large farms balances the decline in small ones. Therefore, in BCS, we did not assume an increase of production.

Table 4. Food production in 2010 based on CSO and future production in 2020 and 2030 in GE (10^6 kg dry mater per year).

Year	Scenario	
	BCS	FVS
2010	93.76	93.76
2020	93.76	112.14
2030	93.76	129.97

Different assumptions were made for the FVS scenario. Using production data from 2004-2010, we predicted a crop's increment as a continuation of trends. In 2020 and 2030, production will be higher by 19.6 and 38.6 %, respectively (Table 4). For Poland, crops are expected to increase by 0.4, 0.7, 0.8 and 0.9% y^{-1} for vegetable, cereal, fruits and rapeseed, respectively. Moreover, a high increase of poultry production is expected. Literature review provides a broad range of studies that predict future yield developments [7, 13, 24]. However, differences between yield growth projections among studies are significant. Enhancing the crop yields affects not only the increasing availability of food but also land for non-agricultural purposes.

Table 5. Average crop and meat production in ton (10^6) and GE (10^6) with standard deviations, and average yield in a ton per ha.

Products	Mean 2008-2010 in t	Mean 2008-2010 in GE	Average yield t ha^{-1}
Cereals (wheat, rye, barley, oat, triticale)	22.6±1.1	18.57	3,4
Potatoes	9.5±0.8	3.78	19.7
Vegetables	5.3±0.3	4.53	22.8
Fruits	3.4±0.5	6.74	9.1
Beef	0.4±0.0	4.04	
Pork	1.9±0.1	12.15	
Poultry	1.8±0.1	15.16	
Cow's milk (Ml)	12.4±0.1	17.96	
Hen eggs (M item)	10.3	3.17	
Sugar beets	9.85		49.7
Rapeseed	2.28		27.2

In our study, the self-sufficiency ratio increased from 1.58 (e.g. 2010 year) to 1.63 in BCS scenario (e.g. 2030 year), and 1.88 in FVS scenario (e.g. 2030 year). The values of this index are similar to the assumptions made in other scientific studies [27].

Table 6 presents a surplus of agricultural land for both scenarios. In 2010, excess area amounted to 1.98 Mha land. In BCS 2.06 and 2.38 Mha, in 2020 and 2030, agricultural land will be available for non-food crops, respectively. In comparison to 2010, the FVS estimates surpluses of land at 3.01 and 3.94 Mha, in 2020 and 2030, respectively. The higher areas in the BCS scenario are due to decrease of population compared to 2010. In addition to this factor, FVS implemented changes in the diet and production which lead to a rise of excess land.

Table 6. Surplus of agricultural land available for biomass production in ha (10^6) and %.

Year	Scenario ha		Scenario %	
	BCS	FVS	BCS	FVS
2010	1.98	1.98	13.63	13.63
2020	2.06	3.01	14.23	20.85
2030	2.38	3.94	16.57	27.45

Similar results as in the FVS scenario were recorded by Simon and Wiegmann [23] using the HEKTOR model, in a referenced scenario. In this scenario, the following assumptions were made: trends for the development of population, food consumption, yield increase and productivity in animal production. The trends were calculated based on statistical data on crops and animal production, food demand and population for the last decades from FAO and the EU.

The surplus of an area available for biomass production under these assumptions in 2030 will be around 2.4 Mha arable land and 1.3 Mha grassland. In the sustainability scenario, where more restrictions were involved, the available arable land stagnates around 1.8 Mha. This lower growth is mainly due to the increase of organic farming, which leads to a less intensive animal and plant production, and in turn a higher allocation of the agricultural area towards food.

The results from our analysis can be compared with the results of another research carried out for Poland. According to de Wit and Faaij [6], an excess of land available for the production of biomass by 2030 in Poland, is from 17 to 31% of the total land in the north-west part of Poland, and above 31% in the central and eastern parts of Poland. The key assumption in their study was modernisation of the agricultural sector driven by increased access to financial support.

Conclusions

Agricultural land area is available to the biomass production for energy use in both scenarios. The biomass potential in Poland depends on a number of factors, e.g. population, consumption pattern, food and feed production. In the BCS, under assumptions that the population in Poland decreases and other factors will not change, 86% of land is needed in 2020 for the supply of future food. In 2030, 83% of land is necessary to feed Poland's population. In 2020, the land for the biomass production is higher in the FVC with assumptions that population, diets and production may be changed in the future. Under these conditions, 79% (e.g. year 2020) and 73% (e.g. year 2030) of the agricultural land area in Poland are necessary for food and feed production. The calculation of biomass potential in this study corresponds reasonably well with the results from other studies.

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