ISSN print: 1224-5984
ISSN online: 2248-3942

Rom Biotechnol Lett. 2020; 25(1): 1208-1215
doi: 10.25083/rbl/25.1/1208.1215

Received for publication, December, 10, 2018
Accepted, January, 4, 2019

Original paper

The analysis of the potential for biomass exploitation in the context of bio-economy. Case study: wheat and maize crops

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Abstract The future evolution of the energy sector, the challenges faced by industry, the growth premise, and the role that agriculture plays as a source of energy are key elements of the bio-economy. Biomass production in the vegetal agricultural sector is in line with the concept of sustainable development, reduces carbon dioxide emissions through photosynthetic processes and ensures the development of raw materials and renewable energy resources. This article proposed both an economic analysis of biomass potential, represented by the secondary production obtained in wheat and maize crops, for the period 2008-2017, as well as an estimation of the market value of the secondary production correlated with the potential for capitalizing those two crops. The exploitation of the potential of the secondary production is reflected in the production of bioenergy (thermal, electric) and biofuels, respectively, both for use as animal feed and fertilization of agricultural land, as well as non-polluting biofuels.

Keywords Bioeconomy, potential, biomass, wheat, maize.

To cite this article: COFAS E, TOMA E, URSU A, DOBRE C. The analysis of the potential for biomass exploitation in the context of bio-economy. Case study: wheat and maize crops. *Rom Biotechnol Lett*. 2020; 25(1): 1208-1215. DOI: 10.25083/rbl/25.1/1208.1215

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Introduction

Biomass includes any renewable material of organic nature, including terrestrial vegetation (crops for food and feed use, woody vegetation, energy crops, industrial plants), aquatic (algae, herbaceous) and microorganisms (fungi, yeasts, bacteria), as well as organic waste and residues from agriculture, fish farming, forestry, municipal waste and other waste (USDA [13]). Primary biomass is produced by plant photosynthetic activity, representing the assembly of more or less rapid plant raw materials, directly used, or following a conversion process, in human food, feed, various industries, or for the production of energy (EPURE [8]). The main types of biomass conversion processes can be classified into four groups (PANOUTSOU & al [2]):

- physical (grinding, separation, drying, briquetting, etc.);
- biological / biochemical (fermentation: anaerobic, aerobic, alcoholic);
- thermal (combustion, pyrolysis, gasification, hydro-genation);
- chemical (e.g. biodiesel production from vegetable / animal oils and fats).

Biomass, as a strategic resource, is an important economic factor because it is a continuous, renewable and practical, inexhaustible energy, but also a guarantor of safety and economic sustainability. It is practically accessible to any area and offers both vital products (e.g. food, feed, raw materials for various industries, biofuels and others) as well as socio-economic develop-ment, especially in rural areas (COFAS & TOMA [3]). The need to integrate both renewable resources and the elements that involve the production, transformation and use of biological materials and products has led to the emergence of bioeconomy (we can say it means "biologizing the economy" (EICKHOUT [1]). In the Romanian National Strategy for Research, Development and Innovation 2014-2020, bioeconomy is considered a national area of intelligent specialization. There are many aspects related to the emergence of bio-economy:

- increasing biomass and increasing demand for biomass generation and refinement in industry;

- waste growth has led to innovative initiatives linked, for example, to the integration of livestock production into the values of other industries (TOMA & al [5]);

- "emerging greenhouse gas mitigation markets boost incentives for biomass stocks (rather than food production) to seize and regenerate the biosphere" (VON BRAUN [7]).

All programmatic documents related to structural and national strategies refer to the agricultural potential (which means, first of all, field crop cultivation), respectively to the secondary production obtained from cereals, as a primary source of biomass. In the budget of any culture, both the value of the main production and the secondary production are highlighted – this can be capitalized both in the field of agricultural production and outside the agricultural production sector. Among different sources of biomass, the crop biomass both as residues or energy plants is one of great importance. Energy plants could be of interest especially when do not compete with food and feed plants, as well as when they put into value the marginal lands or they are using the periods between crop cycles (EUROPABIO [9]). Based on all these considerations, the energy potential of secondary production falls into the energy market in agriculture.

Materials and Methods

The working methodology of this paper implied the implementation of some activities oriented towards the utilization of bioenergy in agriculture, by means of biotechnology-specific conversion methods, having as a basis the four value chains defined at european level (EUROPEAN COMMISSION [10]):

- ✓ value chain 1 (LC1) – "From lignocellulosic raw materials to advanced biofuels, chemicals made from bioresources and biomaterials";
- ✓ value chain 2 (LC2) – "The new generation of value chain based on forestry";
- ✓ value chain 3 (LC3) – "The new generation of value chain on agricultural bases";
- ✓ value chain 4 (LC4) – "New emerging value chains (organic) waste".

Romanian National strategies mainly refer to LC3, as the potential of value chains associated with agriculture / field crops is obviously underutilized, so that for Romania it is possible to delimit an area of agro-bio-economy, respectively of value chains which is based on plant production. Starting from the agricultural base of the LC3 value chain, this paper proposed both an estimation of the potential of the secondary production (as a source of biomass), represented by the secondary productions obtained during 2008-2017 in the wheat and maize crops, as well a estimate of the market value of secondary production compared to the production potential of the two crops. As inputs, the series of data recorded during 2008-2017 (INS source) were used for the following variables:

→ the average annual yields (mean yield, expressed in kilograms per hectare), from which the *maximum yield*, *minimum yield* and *production value range* (as the difference between the maximum yield and the minimum production) were analyzed and the *average* (as indicator for central trend characterization), respectively the *standard deviation* (as an indicator for characterization of variability as a measure of the data set dispersion);

→ the average values of usable agricultural land (average UAA – thousands of hectares);

→ the average annual purchase prices (RON/kilogram) and the annual values of the consumer price index (CPI); using that index were calculated the *average purchase prices*, updated at the level of 2017 for the wheat and maize production. Subsequently, these prices were applied to the coefficients related to the secondary production of wheat and maize and the *average prices of the secondary productions*, updated at the level of 2017, were obtained according to the following formula:

price secondary production = average purchase price × coefficient secondary production

where the secondary production coefficient is 0.15 for wheat and 0.045 for maize (source: ICEADR Bucharest).

Table 1. Input variables

Regions	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Mean	Std.
Wheat – Average yield (kg/ha)												
Centre	3283	2789	2753	3656	2647	3312	3699	3736	3795	4263	3314	542.9
North-East	3205	2615	2696	3366	2317	3173	3340	3029	3609	4313	3037	653.3
North-West	3445	2228	2920	3620	2968	3811	3843	3891	3380	4255	3340	616.3
South	3535	2330	2621	3822	2669	3772	3746	4039	4110	5127	3366	1010.5
South-East	3572	2142	2725	3732	2353	3224	3486	3702	4202	5060	3238	973.3
South-West	3054	2607	2478	3219	2396	2831	3197	3326	3315	4735	2904	900.2
West	3437	2806	2993	4032	3878	4342	4005	4451	4658	5274	3874	773.2
Maize – Average yield (kg/ha)												
Centre	3845	3826	4428	4668	2542	4299	5147	4025	4747	5767	4204	881.6
North-East	3676	3399	3881	4239	1976	4541	4967	3147	3569	5594	3673	1161.5
North-West	4037	3429	4275	4425	2730	4269	4621	3156	4263	5912	3991	882.5
South	3026	3824	4583	4963	2552	5199	5294	4067	4162	6643	4114	1467.0
South-East	2409	2451	4337	4759	1677	4261	4526	3313	3939	5859	3490	1423.1
South-West	2843	3801	4303	4061	1458	4257	4137	2958	3433	6410	3504	1421.2
West	3589	3498	4557	4480	2890	4201	4711	3703	5688	5300	4114	908.1
Wheat – Average UAA (thou ha)												
Centre	102.2	108.8	92.7	99.1	76.3	90.0	91.3	89.5	90.7	88.6	93.3	8.1
North-East	167.4	161.9	156.2	137.3	182.9	152.7	158.4	168.0	167.8	149.3	161.0	11.6
North-West	124.5	124.6	116.2	120.1	118.2	119.5	122.9	146.6	144.7	142.9	128.6	10.9
South	613.0	644.3	628.7	600.0	637.6	597.6	590.6	585.4	588.0	582.4	602.5	24.6
South-East	501.8	497.9	528.2	421.6	466.2	515.0	507.0	499.9	479.8	452.7	476.7	43.8
South-West	379.2	381.8	403.7	350.0	311.3	387.2	382.0	363.8	399.7	404.8	378.0	26.4
West	207.0	215.1	219.3	203.5	186.8	222.5	242.2	234.8	248.7	214.1	220.0	17.0
Maize – Average UAA (thou ha)												
Centre	135.5	137.9	131.6	144.8	160.1	149.8	153.3	160.8	158.8	162.4	149.3	10.4
North-East	442.7	434.2	428.9	463.9	494.6	453.1	455.3	475.6	479.7	442.2	459.3	20.6
North-West	250.0	214.6	256.5	239.7	237.5	256.5	265.4	276.8	279.5	254.4	258.1	23.5
South	478.7	440.4	391.7	479.9	544.1	484.6	462.5	499.9	470.8	454.6	472.5	36.2
South-East	455.5	429.4	335.9	515.8	500.1	481.7	469.7	471.8	475.3	434.4	457.2	45.3
South-West	382.1	382.3	276.4	386.5	414.3	346.6	349.3	360.5	362.1	324.0	358.1	34.6
West	285.5	288.7	265.1	350.5	372.2	335.5	347.5	348.6	343.6	319.6	319.9	36.5
Secondary production price* (RON/kg), constant prices (2017=100)												
Wheat	0.111	0.071	0.083	0.118	0.123	0.118	0.112	0.114	0.097	0.098	0.106 (0.024 euro)	0.016 -
Maize	0.036	0.022	0.024	0.032	0.035	0.031	0.027	0.028	0.029	0.027	0.029 (0.007euro)	0.004 -

*Data source: 1998-2018 National Institute of Statistics;*1 euro = 4.5 RON*

Results and Discussion

Wheat and maize occupy over half of Romanian arable land (around 4.5 mil hectares). In the last decade (2008-2017), at country level, thewheat yield varied from a value of 1541 kg/ha to a value of 4888 kg/ha (std. of 859 kg/ha) and the maize yield from a value of 1526 kg/ha to a value of 5959 kg/ha (std. of 1183 kg/ha). At regional level, the wheat presented a great variability, from a value of 789 kg/ha in South-West Region to a value of 5274 kg/ha in West Region (Fig. 1). The situation was similar for maize for which the average yield varied from a minimum of 863 kg/ha in South-East Region to a maximum of 6643 kg/ha in South Region (Fig. 2).

In 2008-2017 period, the regions Centre and Nord-West registered the lowest standard deviation of wheat and maize (around 600 kg/ha for wheat and 880 kg/ha for maize). Region West had the higher average yield of wheat (3874 kg/ha) and the Centre Region the higher average yield of maize (4204 kg/ha) (Fig. 3). The regions from south of the country, which concentrate over 50% (even till 70%) of the cultivated area with wheat and maize, are affected more by variability due to pedoclimatic conditions and lack of irrigations (higher deviations).

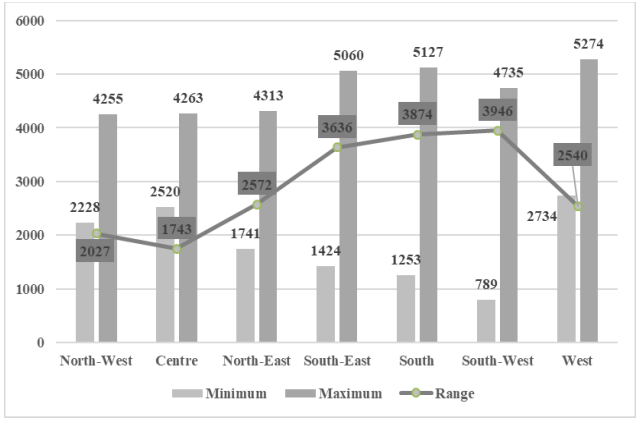

Figure 1. Wheat – Minimum, maximum and range – yield (kg/ha), 2008-2017

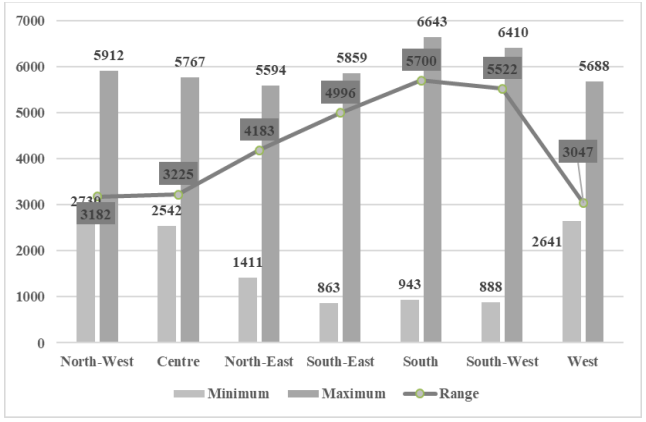

Figure 2. Maize – Minimum, maximum and range – yield (kg/ha), 2008-2017

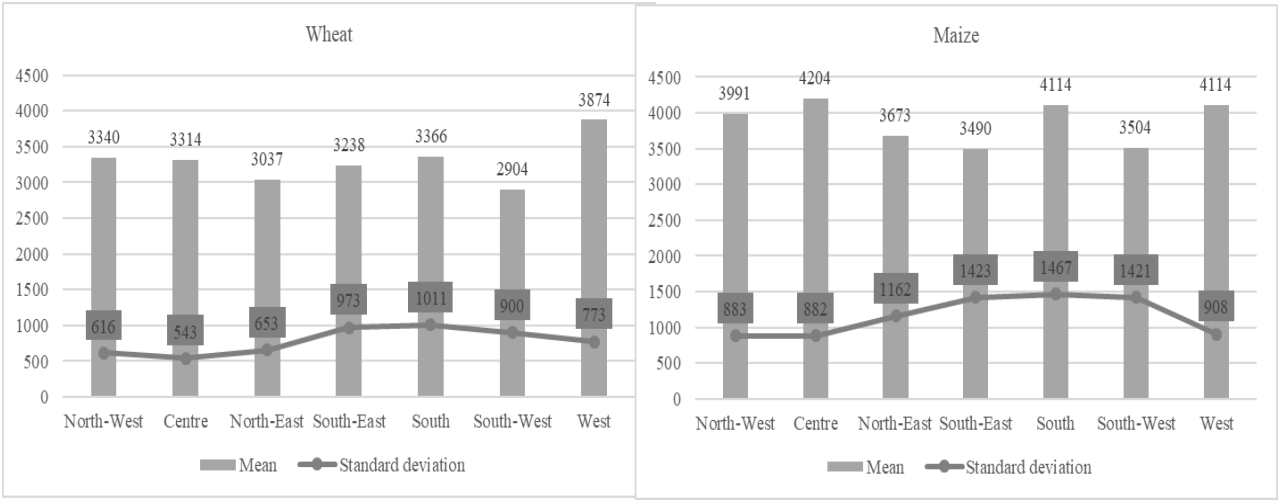

Figure 3. Wheat and maize – Mean and standard deviation – average yield, 2008-2017

In the analysed period, these yield fluctuations, due especially to climatic conditions, lack of irrigation systems and inefficient mix of inputs, represented an impediment in reaching the optimum level of productivity. According with the research studies on around 3000 villages, the maximum potential yield on hectare in our country is for wheat of 5622.3 kg/ha and for maize of 8017.9 kg/ha and according with Ministry of Agriculture and Rural Development – Romania (MADR), official data the crop potential is 3500 kg/ha for wheat and 4100 kg/ha for maize, in non-irrigated systems, and 6000 kg/ha for wheat and maize, in irrigated systems (MADR [11]).

The average values of yield, recorded in 2008-2017 periods at regional level, are between 2600-3200 kg/ha for wheat and between 3300-4400 kg/ha for maize (Table 2). In these conditions, if we compare the average data from each region with the maximum official level of potential yield, we may observe that we are far away from the maximum level of productivity, even for non-irrigated systems.

Regarding the wheat sector (Table 3), Romania cultivates annually an average UAA of 2.1 mil. ha. In this case, we estimate that the secondary production is in average of 2.4 mil.tons which is under the real potential for this crop, in Romania can be obtain, in optimal conditions (specific for irrigated systems), until 4.3 mil. tons from which over 70% in the southern regions.

Table 2. Wheat and maize – Share of mean and maximum yields in average and maximum production potential

Regions	Wheat					Maize				
	Average Yield (kg/ha)	Maximum potential yield of wheat non-irrigated (kg/ha)	Share (%)	Maximum potential yield of wheat irrigated (kg/ha)	Share (%)	Average Yield (kg/ha)	Maximum potential yield of maize non-irrigated (kg/ha)	Share (%)	Maximum potential yield of maize irrigated (kg/ha)	Share (%)
Centre	3314	3500	94.7	6000	55.2	4204	4000	105.1	6000	70.1
North-East	3037	3500	86.8	6000	50.6	3673	4000	91.8	6000	61.2
North-West	3340	3500	95.4	6000	55.7	3991	4000	99.8	6000	66.5
South	3366	3500	96.2	6000	56.1	4114	4000	102.9	6000	68.6
South-East	3238	3500	92.5	6000	54.0	3490	4000	87.3	6000	58.2
South-West	2904	3500	83.0	6000	48.4	3504	4000	87.6	6000	58.4
West	3874	3500	110.7	6000	64.6	4114	4000	102.9	6000	68.6

Table 3. Wheat – Estimation of average secondary production for 2008-2017 compared with the potential

Regions	Average Yield (kg/ha)	Secondary production (kg/ha)*	Maximum potential yield of wheat Non-irrigated (kg/ha)	Secondary production (kg/ha)	Maximum potential yield of wheat Irrigated (kg/ha)	Secondary production (kg/ha)	Average UAA (ha)	Total average secondary production (tones)	Total secondary production potential Non-irrigated (tones)	Total secondary production potential Irrigated (tones)
Centre	3314	1160	3500	1225	6000	2100	128647	149218	157593	270159
North-East	3037	1063	3500	1225	6000	2100	93334	99209	114334	196001
North-West	3340	1169	3500	1225	6000	2100	161049	188266	197285	338203
South	3366	1178	3500	1225	6000	2100	476656	561548	583904	1000978
South-East	3238	1133	3500	1225	6000	2100	602542	682861	738114	1265338
South-West	2904	1016	3500	1225	6000	2100	377971	384170	463014	793739
West	3874	1356	3500	1225	6000	2100	220040	298352	269549	462084
TOTAL							**2060239**	**2363625**	**2523793**	**4326502**

**Coefficient 0.35, ICEADR Bucharest source*

Regarding the maize sector (Table 4), Romania cultivates annually an average UAA of 2.5 mil. ha. The secondary production is estimated at an average level of 4.3 mil. tones, also under the real potential for this crop, in optimal conditions (specific for irrigated systems), we can obtain almost 6.7 mil. tones of secondary production, concentrated especially in regions South-East, North-West and South.

Table 4. Maize – Estimation of average secondary production for 2008-2017 compared with the potential

Regions	Average Yield (kg/ha)	Secondary production (kg/ha)*	Maximum potential yield of wheat Non-irrigated (kg/ha)	Secondary production (kg/ha)	Maximum potential yield of wheat Irrigated (kg/ha)	Secondary production (kg/ha)	Average UAA (ha)	Total average secondary production (tonnes)	Total secondary production potential Non-irrigated (tonnes)	Total secondary production potential Irrigated (tonnes)
Centre	4204	1892	4000	1800	6000	2700	258072	488221	464530	696794
North-East	3673	1653	4000	1800	6000	2700	149322	246807	268780	403169
North-West	3991	1796	4000	1800	6000	2700	459302	824883	826744	1240115
South	4114	1851	4000	1800	6000	2700	457235	846479	823023	1234535
South-East	3490	1571	4000	1800	6000	2700	472509	742075	850516	1275774
South-West	3504	1577	4000	1800	6000	2700	358107	564663	644593	966889
West	4114	1851	4000	1800	6000	2700	319857	592151	575743	863614
TOTAL							**2474404**	**4305280**	**4453927**	**6680891**

**Coefficient 0.45, ICEADR Bucharest source*

Starting from previous data, for wheat (Table 5) we calculated that the average annual value of secondary products market in of 56.73 mil euro. By not improving the yields, at a level of non-irrigated systems, Romanian wheat sector loosed annually around 4 mil euro and by not reaching the full potential (specific for irrigated systems) loosed around 47 mil euro.

For maize (Table 6) we estimated that the average annual value of secondary products market in of 30.14 mil euro. In our opinion, by improving the yields at least at the level of non-irrigated systems, the maize sector can gain annually around 1 mil euro and by reaching the maximum production on hectare (specific for irrigated systems) it can gain around 17 mil euro.

Table 5. Wheat – Estimation of secondary production market value compared with the potential

Regions	Total average secondary production (tons)	Total secondary production potential Non-irrigated (tons)	Total secondary production potential Irrigated (tons)	Total estimated value of secondary production (mil euros)*	Total estimated value of potential secondary production Non-irrigated (mil euros)	Total estimated value of potential secondary production Irrigated (mil euros)	Gap from potential Non-irrigated (mil euros)	Gap from potential Irrigated (mil euro
Centre	149218	157593	270159	3.58	3.78	6.48	0.20	2.90
North-East	99209	114334	196001	2.38	2.74	4.70	0.36	2.32
North-West	188266	197285	338203	4.52	4.73	8.12	0.22	3.60
South	561548	583904	1000978	13.48	14.01	24.02	0.54	10.55
South-East	682861	738114	1265338	16.39	17.71	30.37	1.33	13.98
South-West	384170	463014	793739	9.22	11.11	19.05	1.89	9.83
West	298352	269549	462084	7.16	6.47	11.09	-0.69	3.93
TOTAL	**2363625**	**2523793**	**4326502**	**56.73**	**60.57**	**103.84**	**3.84**	**47.11**

**Average price 0.106 RON/kg (0.024 euro/kg), 1 euro = 4.5 RON*

Table 6. Maize – Estimation of secondary production market value compared with the potential

Regions	Total average secondary production (tons)	Total secondary production potential Non-irrigated (tons)	Total secondary production potential Irrigated (tons)	Total estimated value of secondary production (mil euros)*	Total estimated value of potential secondary production Non-irrigated (mil euros)	Total estimated value of potential secondary production Irrigated (mil euros)	Gap from potential Non-irrigated (mil euros)	Gap from potential Non-irrigated (mil euros)
Centre	488221	464530	696794	3.42	3.25	4.88	-0.17	1.46
North-East	246807	268780	403169	1.73	1.88	2.82	0.15	1.09
North-West	824883	826744	1240115	5.77	5.79	8.68	0.01	2.91
South	846479	823023	1234535	5.93	5.76	8.64	-0.16	2.72
South-East	742075	850516	1275774	5.19	5.95	8.93	0.76	3.74
South-West	564663	644593	966889	3.95	4.51	6.77	0.56	2.82
West	592151	575743	863614	4.15	4.03	6.05	-0.11	1.90
TOTAL	**4305280**	**4453927**	**6680891**	**30.14**	**31.18**	**46.77**	**1.04**	**16.63**

**Average price 0.029 RON/kg (0.007 euro/kg), 1 euro = 4.5 RON*

For 2008-2017 periods, the market of secondary products (wheat and maize) is estimated at a value of 868.6 mil euro. Thus the estimated value of potential inputs for bio-based industry reached 567.3 mil euro for wheat and 301.4 mil euro for maize (Table 7).

However, we observe that, if the farms can obtain maximum yields, this sector can reach a value of 1506.0 mil euro, 69% from wheat sector and 31% from maize sector. This means that, in the 2008-2017 periods, bio-based industry loosed raw materials of almost 640 mil euro.

Table 7. Estimation of 10 years secondary production market value compared with the potential

Regions	**Wheat** The estimated value of bio-based industry 2008-2017 (mil euros)	**Maize** The estimated value of bio-based industry 2008-2017 (mil euros)	Total secondary production 2008-2017 (mil euros)	**Wheat** Market potential for 10 years (mil euros)	**Maize** Market potential for 10 years (mil euros)	Total market potential for 10 years (mil euros)	Loss by not reaching the potential (mil euros)
Centre	35.81	34.18	69.99	64.84	48.78	113.61	43.62
North-East	23.81	17.28	41.09	47.04	28.22	75.26	34.17
North-West	45.18	57.74	102.92	81.17	86.81	167.98	65.06
South	134.77	59.25	194.02	240.23	86.42	326.65	132.63
South-East	163.89	51.95	215.84	303.68	89.30	392.99	177.15
South-West	92.20	39.53	131.73	190.50	67.68	258.18	126.45
West	71.60	41.45	113.05	110.90	60.45	171.35	58.30
TOTAL	**567.27**	**301.37**	**868.64**	**1038.36**	**467.66**	**1506.02**	**637.38**

From the presented analysis we can see that the biomass, expressed quantitatively by the value of the secondary production, is a promising renewable energy source for Romania, both in terms of its potential and the possibilities of its use. Certainly it can be said that the market potential of biomass is very high, both for wheat and maize. In our opinion, by improving yields, at least at the level of non-irrigated systems, the wheat sector can earn about EUR 4 million a year, and maize can earn about EUR 1 million annually. Extrapolating, by reaching the maximum yield per hectare ((specific to irrigated systems), they can get up to 47 million euros for secondary wheat production and 17 million for maize.

Although secondary production is reduced compared to the main production, it does not reflect the true value of the market, even if only a part of the secondary production is used in the development of these biomass-based raw materials industries. From this analysis it can be deduced that the prospect of superior utilization of biomass by suitable methods may lead to a vision of the use of bio-mass in the context of the national bio-economy.

Research and development policies have identified more needs related to bio-economy, which should materialize in new technologies, biological products, biomass types, production techniques etc. (COFAS & al [4]). The requirements of the current stage of development for unconventional activities in the rural area impose specific energy market requirements resulting from the capitalization of secondary production. Regarding this problems it can be mentioned some of the advantages resulting from the use of biomass, namely (TOMA [6]):

- obtaining and easy renewal of these products through different conversion methods that can be used to produce energy (thermal, electrical);
- use as animal feed and fertilization of agricultural land;
- use as a fuel that does not raise environmental pollution problems.

Based on all these considerations, the energy potential of the by-products falls into the energy market in agriculture. Limiting valorisation within a particular production system no longer meets current requirements, so that, for this reason, the energy value of secondary agricultural production must be integrated into a global energy market (OCED[12]).

Conclusions

The economic analysis carried out in this paper highlights the huge potential of secondary production, if it is fully exploited. However, we must bear in mind that the use of this secondary production exclusively as a renewable energy resource would affect the biological balance of the soil. Maintaining and increasing soil fertility are primarily conditioned by the quantity and quality of organic matter in the soil. In the easiest and safest way, sources of organic matter for the soil come from crop residues, ie from secondary agricultural products. Thus, many farmers are not interested in the economical quantification of biomass from grain cultivation and export of secondary production, available as renewable energy resources, because it is more convenient for them to leave these secondary products as organic matter for soil.

In conclusion, the problems of capitalizing on the secondary production in agriculture follow at the present stage tendencies related to a double aspect: first of all one can refer to the existence and accentuation of the energy crisis of the fossil fuels, and secondly to the pollution and protection of the systems ecological. All these aspects mean for the "biomass-energy-ecology" ensemble a new form for the market of energy from secondary agricultural production, considering here also the qualitative aspect regarding the biomass content and the current energy conversion possibilities, which in the end will lead to finding the most appropriate and accessible forms of rational use and valorisation of biomass in the context of building and developing the bio-economy.

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