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OPPORTUNITIES FOR CIRCULAR BIOECONOMY DEVELOPMENT IN THE ROMANIAN CEREAL SECTOR

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ABSTRACT - The circular economy offers a development model that seeks to optimize resource use by reducing waste, reusing materials and valorizing by-products. In agriculture, the adoption of circular principles is becoming increasingly important in response to growing pressure on natural resources and the need to minimize environmental impacts. Romania’s cereal sector, a key component of national agricultural production, generates significant quantities of residues and secondary products that hold considerable potential for circular bioeconomy applications. Integrating these resources into sustainable value chains can enhance farm profitability, improve resource efficiency, and strengthen the resilience of agro-food systems. Our study provides an analysis of circular economy principles and their applicability in agriculture, complemented by an overview of global practices and their current uptake in Romania. This framework supports the identification of opportunities to improve resource efficiency and circularity within agricultural systems. We examine the structure of cereal cultivation and map the waste streams and by-products generated from key crops such as wheat, barley, triticale, and maize. Regional data on secondary product availability illustrate the spatial distribution of resources and their potential for valorization. Several opportunities for waste reduction and the circular use of cereal residues were identified. Overall, the findings highlight concrete pathways for developing integrated circular value chains that support environmental objectives and strengthen economic resilience within Romanian agriculture.

Introduction - Fossil fuels are limited and their intensive use has caused significant environmental changes, making the transition to cleaner energy sources, such as solar, hydro, nuclear and biofuels more urgent than ever. To address these challenges, the European Commission (2022) promotes a circular economy, aiming to keep resources in use as long as possible, minimize waste and reduce environmental impacts. In agriculture, circular economy principles transform crop residues into valuable resources for soil fertility, bioenergy and other applications. Biomass can also be converted into biofuels for heat, electricity, transport, reducing reliance on fossil fuels. Practices such as agroforestry, crop rotation, composting, organic and regenerative farming enhance soil health, support biodiversity, mitigate climate change and create economic value from by-products. In Romania, where agriculture contributes significantly to greenhouse gas emissions and environmental degradation, adopting circular approaches is crucial for building sustainable, resilient and productive food systems.

Cereal production and circular opportunities - Cereals are a cornerstone of global agriculture, feeding billions of people while also providing essential nutrition for livestock and raw materials for a wide range of industrial uses, from food products to biofuels and biomaterials. Major cereals, such as wheat, maize and barley, have specific cultivation needs and uses. While their roles vary, together they contribute significantly to food production, agricultural diversity and the generation of by-products that can be valorized in circular agricultural systems. Production of cereals generates residues at every stage:

- Pre-harvest residues: leaves, stalks - often returned to the soil to maintain fertility.
- Post-harvest residues: straw, husks, bran, non-viable grains - can be reused in circular systems.
- Processing residues: dust, fine particles, by-products from oil extraction or milling.

By viewing these residues as resources, farmers can reduce waste, lower environmental impact, and create economic value. Examples of circular uses: crop residues → compost or biofertilizers; husks and bran → raw materials for bioenergy or biomaterials; non-viable grains → animal feed or industrial inputs.

Table 1 - Cereal production and circular by-products (based on FAO and Statistics estimates for 2023-2024)

Cereal	Main cultivation regions	Global production (t/year)	Key residues / Potential circular uses
Wheat	Temperate regions worldwide	~750 million	Straw (mulch, compost), bran (animal feed, bio-materials), husks (bioenergy), non-viable grains (feed/industry)
Maize	America, Africa, Asia	~1,235 million	Stalks (mulch, compost), husks & cobs (bioenergy), bran (feed, biomaterials), non-viable kernels (feed/industry)
Rice	Tropical & subtropical Asia	~514 million	Straw (compost, soil amendment), husks (bioenergy, industry), bran (feed), broken grains (feed, industry)
Barley	Europe, North America, Asia	~143 million	Straw (compost), husks (bioenergy), bran (feed), non-viable grains (feed)
Oats	Europe, North America, Russia	~19.4 million	Straw (compost), husks (bioenergy), bran (feed), dust (bio-materials)
Sorghum	Africa, Asia, North America	~60 million	Stalks (compost, bioenergy), husks (bioenergy), bran (feed), non-viable grains (feed)
Millet	Asia, Africa	~30 million	Stalks (compost), husks (bioenergy), bran (feed), non-viable grains (feed)

Table 2 - Grain and residue yields ratios for major cereal crops

Crop	Grain: residue ratio	Notes
Wheat	1 : 1	Varies with cutting height, cultivar and yearly conditions
Barley	1 : 1.5	Higher straw yield compared to wheat
Maize	1 : 1.5	Lower biomass due to modern shorter hybrids

Table 3 - Total and secondary production (estimated) for wheat by Macro-regions and Counties

Macro-regions/County	2021		2022		2023		2024	
	Prod/Second tonnes	Prod/Second tonnes	Prod/Second tonnes	Prod/Second tonnes	Prod/Second tonnes	Prod/Second tonnes	Prod/Second tonnes	Prod/Second tonnes
TOTAL	10433751	8684237			9624074		9290875	
MACROREGION 1	1075180	987734			1088253		1096226	
BIHOR	353051	30820			356209		384893	
BISTRITA-NASAUD	14679	14824			12953		12512	
CLUJ	54540	52649			52931		57621	
MARAMURES	13593	13856			11683		11126	
SATU MARE	199991	174731			207154		199757	
SALAJ	32199	33460			30861		32570	
ALBA	61238	58894			64514		63593	
BRASOV	37068	35565			44202		38415	
COVASNA	97039	88342			82084		90345	
HARGHITA	54764	51181			41599		40975	
MURES	130831	118871			159988		142792	
SIBIU	26187	24541			24075		21627	
MACROREGION 2	3336082	2194568			2733138		2439836	
BACAU	97889	53507			93578		93815	
BOTOSANI	152326	115074			146937		108554	
IASI	225452	107631			189866		160900	
NEAMT	108192	87843			111221		107375	
SUCEAVA	83648	71691			99593		91919	
VASLUI	268673	171259			222363		189765	
BRAILA	359182	267758			374168		320705	
BUZAU	315402	109153			257295		85950	
CONSTANTA	836548	811647			698448		836503	
GALATI	408811	116263			182578		108672	
TULCEA	363564	246493			254687		298719	
VRANCEA	116395	36249			102404		36959	
MACROREGION 3	3018082	2701457			2835626		2827656	
ILFOV	118042	83904			91674		84037	
ARGES	221375	190039			214815		179645	
CALARASI	665414	609747			503261		626934	
DAMBOVITA	105996	117352			149957		118446	
GIURGIU	423198	394260			400268		490287	
IALOMITA	548544	460478			476485		430081	
PRAHOVA	159230	146429			196843		121312	
TELEORMAN	776283	699248			802323		776914	
MACROREGION 4	3004407	2800478			2967057		2927157	
DOLJ	945187	782903			790791		785778	
GORJ	42512	42209			36513		36271	
MEHEDINTI	193018	180006			202441		172840	
OLT	653954	567052			653556		594473	
VALCEA	34199	25812			29486		28764	
ARAD	416414	362768			426533		461920	
CARAS-SEVERIN	66956	64877			89003		80080	
HUNEDOARA	35369	32449			35494		33466	
TIMIS	616798	742402			703240		733565	

Table 4 - Total and secondary production (estimated) for barley and malting barley by Macro-regions and Counties

Macro-regions/County	2021		2022		2023		2024	
	Prod tonnes	Second tonnes	Prod tonnes	Second tonnes	Prod tonnes	Second tonnes	Prod tonnes	Second tonnes
TOTAL	1981030	2971545			1706650		2559975	
MACROREGION 1	154466	231699			140658		210987	
BIHOR	23608	35412			21931		32897	
BISTRITA-NASAUD	4714	7071			5405		8108	
CLUJ	33275	49913			29838		44757	
MARAMURES	1376	2064			1312		1968	
SATU MARE	11537	17306			11070		16605	
SALAJ	5628	8442			3852		5778	
ALBA	9199	13799			8668		13002	
BRASOV	9893	14840			8014		12021	
COVASNA	12413	18620			10106		15159	
HARGHITA	16701	25052			15616		23424	
MURES	22533	33800			22518		33777	
SIBIU	3589	5384			2328		3492	
MACROREGION 2	878100	1317150			666780		1000170	
BACAU	6464	9696			6049		9074	
BOTOSANI	11255	16883			9774		14661	
IASI	21828	32742			11684		17526	
NEAMT	23433	35150			17161		25742	
SUCEAVA	13248	19872			14697		22046	
VASLUI	18849	28274			14520		21780	
BRAILA	113815	170723			89345		134018	
BUZAU	47359	71039			22579		33869	
CONSTANTA	416660	624990			383403		575105	
GALATI	106607	159911			41243		61865	
TULCEA	84700	127050			52881		79322	
VRANCEA	13882	20823			3444		5166	
MACROREGION 3	573202	859803			541855		812783	
ILFOV	14927	22391			11829		17744	
ARGES	8004	12006			5594		8391	
CALARASI	166211	249317			173033		259550	
DAMBOVITA	25398	38097			32171		48257	
GIURGIU	113492	170238			105747		158621	
IALOMITA	105863	158795			76861		115292	
PRAHOVA	24187	36281			21975		32963	
TELEORMAN	115120	172680			114645		171968	
MACROREGION 4	375262	562893			357357		536036	
DOLJ	140096	210144			118587		177881	
GORJ	1927	2891			1645		2468	
MEHEDINTI	32597	48896			29393		44090	
OLT	85043	127565			83492		125238	
VALCEA	1520	2280			2563		3845	
ARAD	36393	54590			39707		59561	
CARAS-SEVERIN	4620	6930			7797		11696	
HUNEDOARA	1888	2832			2891		4337	
TIMIS	71178	106767			71282		106923	

Table 5 - Total and secondary production (estimated) for maize by Macro-regions and Counties

Macro-regions/County	2021		2022		2023		2024	
	Prod tonnes	Second tonnes	Prod tonnes	Second tonnes	Prod tonnes	Second tonnes	Prod tonnes	Second tonnes
TOTAL	14820693	22231040	8037134	12055701	8743995	13115993	5971854	8957178
MACROREGION 1	2761685	4142528	1787626	2681439	2104238	3156192	1821367	2732051
BIHOR	619076	928614	284432	426648	441239	661859	378120	567180
BISTRITA-NASAUD	84033	126050	82175	123263	70358	105537	60455	90683
CLUJ	242928	364392	172859	259289	170428	255642	156980	235470
MARAMURES	82909	124364	65611	98417	55286	82929	44113	66170
SATU MARE	571767	857651	223230	334845	287941	431912	252494	378741
SALAJ	131441	197162	88524	132786	88557	123936	81217	121826
ALBA	277063	415595	167494	251241	196002	285903	175449	263174
BRASOV	67182	100773	56737	85106	64820	97230	57191	85787
COVASNA	48106	72159	45206	67809	40402	60603	72767	109151
HARGHITA	12567	18851	10599	15899	10223	15335	8698	13047
MURES	472692	709038	465050	697575	520279	780419	428936	643404
SIBIU	151921	227882	125709	188564	163993	245990	109447	157421
MACROREGION 2	6438690	9658035	2618203	3927305	2840764	4261146	1924012	2886018
BACAU	410146	615219	247433	371150	281656	422484	215134	322701
BOTOSANI	740031	1110047	377572	566358	396248	594372	225106	337659
IASI	633817	950726	172735	259103	256037	384056	162231	243347
NEAMT	381875	572813	244350	366525	266392	399588	200808	312012
SUCEAVA	201601	302402	247382	371073	270972	406458	164975	247465
VASLUI	462847	694271	146966	220449	133988	200982	97904	146856
BRAILA	852229	1278344	547948	821922	626199	939299	551670	875605
BUZAU	663972	995958	25574	38361	227753	341630	47710	71655
CONSTANTA	263397	395096	223205	334808	52488	78732	66088	99132
GALATI	1510470	2265705	249362	374043	163797	245696	92322	138483
TULCEA	152351	228527	100710	151065	76249	114374	72675	109013
VRANCEA	165954	248931	34966	52449	88985	133478	20189	30284
MACROREGION 3	3167772	4751658	2002063	3003095	1754253	2631380	886359	1329539
ILFOV	87554	131331	37877	56816	29101	43652	11418	17127
ARGES	201452	302178	185339	278009	206709	310064	93768	140652
CALARASI	941407	1412111	473217	709826	296225	444338	297129	445694
DAMBOVITA	227232	340848	204791	307187	218901	328352	58532	87798
GIURGIU	218929	328394	220594	330891	212098	318147	94001	141002
IALOMITA	959009	1438514	538779	808169	432867	649301	249880	374820
PRAHOVA	243413	365120	177585	266378	206474	309711	12277	18416
TELEORMAN	288776	433164	163881	245822	151878	227817	69354	104031
MACROREGION 4	2452546	3678819	1629242	2443863	2044850	3066275	1340116	2010174
DOLJ	373749	560624	296497	444746	329653	494880	225493	338240
GORJ	192777	289166	17680	326520	201094	301641	163591	245387
MEHEDINTI	150333	225500	146363	219545	150329	225494	43822	65733
OLT	228346	342519	206792	310188	213746	320619	61667	92501
VALCEA	170798	256197	149291	223937	141003	211505	50935	76403
ARAD	471629	707444	227256	340884	312713	469070	284832	427248
CARAS-SEVERIN	81263	121895	65393	98090	62579	93869	65328	97992
HUNEDOARA	87099	130635	72731	109097	74224	111336	70193	105290
TIMIS	696561	1044842	247239	370859	595959	839264	374255	561388