



OPPORTUNITIES – ALTERNATIVES FOR APPLICATION OF AGROECOLOGICAL MEASURES AND USE OF POST-HARVEST RESIDUES

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Abstract

In most of the cases, the standard cultivation of cereal crops by agricultural producers is carried out by applying agricultural practices, which are unsustainable in long term. Especially the treatment of post-harvest residues (mostly burning the stubble of rice, wheat and barley), contributes to the increase of the risk faster and mostly irreversible or very slow reversible degradation of natural resources.

The treatment of the post-harvest residues must be in accordance with the strategies and practices of good agricultural practice, which are compatible with the EU strategy in the field of agricultural policy. Only in Bregalnica region, on an annual level, around 100 000 tons (96,082 tons) of “post-harvest residues” remain on productive agricultural arable land. These amounts are obtained from around 31 100 hectares of arable land on which the most common cereal crops (wheat, corn, barley, rye and oats) are grown. On average, from all crops, on an annual level, about 3,2 t/ha of post-harvest aboveground plant biomass remained, which represents a significant resource, that is often used irrationally and sometimes harmful to the environment, by agricultural producers.

The practice of agricultural cereal crop producers has been analysed and alternative approaches for using post-harvest residues have been proposed. The additional financial implications for farmers, which can be achieved by proper treatments of the post-harvest residues are emphasized. Proposed measures and activities for sustainable management of plant residues after harvest are explained.

Key words: cereals, agricultural practices, degradation, sustainable management

INTRODUCTION

In most of the cases, the conventional cultivation of agricultural crops by farmers is carried out through the application of unsustainable long-term agricultural practices. The low level of adaptability of applied agricultural practices, together with inefficient risk management methods of their application, contributes to increasing the risk degree of faster and most often irreversible or very slow reversible degradation of natural resources.

This type of activities contributes to irreversible disruption of natural biocycles in natural but also in agrobiotopes and agrobiocenosis, associated with a strong reduction on soil fertility and reduction in resistance and functional integrity of ecosystems.

Agricultural producers, especially rice producers in Bregalnica region, in the past

decades and currently, with very rare exceptions, have been implementing a multi-year practice of regular application of unpopular and legal prohibited agricultural measure of burning the post-harvest residues on the stubble. The correct and ecologically sustainable management of biomass obtained from harvest residues, carried out in accordance with good agricultural and hygienic practices (Ministry of Agriculture, Forestry and Water Management, 2010), which are the backbone of agroecological measures (Ministry of Agriculture, Forestry and Water Management, 2014), present a set of pre-planned, comprehensive, systemic and continuous activities and agrotechnical practices, which agricultural producers are recommended to implement in a coordinated manner.

The goal of good agricultural practice is

to determine the correct procedures in the process of agricultural production that would minimize the threats of degradation and the loss of this limited natural resource, and which refer to measures and procedures to preserve and improve soil fertility.

In the agricultural practice during the production of agricultural crops which leave a significant amounts of aboveground plant material, after the harvest in the Bregalnica region, as well as in the country, in an extremely small number of cases, it is acted in accordance with good agricultural practice. Most often, grain producers improperly deal with harvest residues, i.e. they burn them and on this way multiple damages and unwanted consequences are caused for people, animals and the environment.

In our country, in several official (published in the Official Gazette) laws, (for agricultural land, for hunting, for forests, for the environment, for nature protection), are foreseen penal provisions for lighting fire in the open air. A lot of articles of those laws, also contain and describe in detail the procedures that are prohibited to be carried out in the open field, which are related to burning the stubble and other plant residues, and high penalties are predicted for legal and natural persons.

In some parts of the law of environmental protection (Official Gazette of the Republic of Macedonia, 2005), is predicted the implementation of sustainable use of natural resources with a little disturbance of the natural balance and insignificant damages. This law also prohibits permanent disturbances of the natural balance by implementing agrotechnical measures recognized as harmful to the natural composition, development and maintenance of an ecological healthy environment. Common practices for burning post-harvest residues are contrary and violate the provisions of the environmental protection law, in which it is contained:

„In order to avoid destruction and degradation with long-term effects, a ban of on the use of nature is being approached in causes where it can cause: damage or destruction of biological and regional diversity; soil degradation and loss of its fertility; damage of surface or underground geomorphological values; pollution and change of water and air pollution.”

The handling of post-harvest residues should necessarily be in accordance with the strategies and good agricultural practice, which are compatible with EU strategy in the field of agricultural policy, where stimulation of farmers for the use of agricultural land is predicted with adopted legal regulations which relate on a way that is consistent with the protection of environmental and biological diversity.

The principles of good agricultural practice usually predict: reduced or minimal soil tillage, application of an appropriate crop rotation with inclusion of cover crops, as well as use of organic fertilizers.

Plant biomass that remains after crop harvest, especially cereals, is an excellent raw material for its conversion into an energy or value-added product with use for many different purposes in agricultural production.

Beside being used for renewable energy source, plant post-harvest residues also can be used for: organic soil fertilizers; substrate for mushroom production; material for composting; fodderfood; raw materials in furniture production; paper and building materials industries; directly for burning.

In this paper, the types and the volume of cultivated cereals in Bregalnica region my municipalities will be explained, as well as the yields obtained by them, the current situation with the management of harvest residues, farmers practice, alternative approaches for using post-harvest residues, additional financial farmers implications for straw collection, as well as proposing measures for sustainable management with harvest residues.

MATERIAL AND METHODS

- The following basic sources of data are used:
- officially published data from SSO (State Statistical Office);
 - data from original scientific research published in domestic and foreign scientific journals in this field;
 - data from publications, project reports and monographs;

- data from the regional units of the Ministry of Agriculture, Forestry and Water Management (2014);
 - data that results based on the practice of farmers.
- Below are presented the methodologies used for this manuscript:
- recognition and collection of data, their

- preparation, grouping, validation, tabular and text presentation and analysis;
- average annual hectares of cultivated cereals in the Bregalnica region by municipalities and obtained yields;
 - the weight of the post-harvest biomass was theoretically calculated and analysed;
 - methods and analyses (SWOT), oriented to the possibilities of the resource;
 - description and analysis of the current situation with the management of harvest residues;
 - field surveys with producers;
 - alternative approaches for the use of harvest residues.

The biomass which remains on the agricultural land after harvest, could be estimated using various methodologies, assumptions and data. Statistical methods were used, oriented to the possibilities of the source. For more detailed

analyses, it is necessary to assess: the theoretical and technical potential, as well as economic source potential.

The theoretical potential is the maximum amount of harvestable biomass, which is available according to the potential of its source. Technical potential is a part of the theoretical potential, which can be used for energy needs or for its use as a raw material for other purposes, taking into account the limitations related to the current technological possibilities, the possible use of live human labour, as well as environmental limitations. Economic potential is the potential that can be used under current economic conditions, i.e. it satisfies the criterion of being profitable.

The data for total post-harvest biomass, explained in this paper, are calculated based on the theoretical potential of harvest biomass.

RESULTS AND DISCUSSION

Grain production and post-harvest residues from cereals crop in Bregalnica region

In Table 1 data of wheat and corn grain production in 2017, in thirteen municipalities in Bregalnica region are presented.

Table 1. Production of wheat and corn grain, by municipalities in the Bregalnica region in 2017.

Bregalnica region-municipalities	Wheat				Corn			
	Area (ha)		Production		Area (ha)		Production	
	Sown area	Harvested area	Total t (tons)	Yield kg/ha	Sown area	Harvested area	Total t (tons)	Yield kg/ha
Berovo	366	366	1 024	2 798	135	135	225	1 667
Vinica	287	287	575	2 002	263	263	2 362	8 981
Delcevo	829	829	1 480	1 786	709	707	1 439	2 035
Zrnovci	229	224	572	2 555	294	258	1 878	7 278
Karbinci	1 081	1 041	1 068	1 026	382	318	1 265	3 978
Kocani	626	626	1 513	2 417	393	383	2 901	7 573
Lozovo	668	668	1 136	1 700	22	22	25	1 136
Makedonska kamenica	71	71	126	1 770	87	87	146	1 672
Pehcevo	422	422	1 271	3 011	84	84	198	2 362
Probistip	1 507	1 507	3 261	2 164	248	248	330	1 332
Sveti Nikole	3 160	3 160	4 988	1 579	477	477	388	814
Cesinovo - Oblesevo	831	831	2 282	2 746	860	860	7 230	8 407
Stip	1 015	1 015	826	814	157	157	576	3 668
Total ha/ t (tons)/	11 092	11 047	17 918	1 622	4 111	3 999	18 963	4 742
Average (kg/ha)								

Source: Statistical Review: Agriculture (Statistical Office of the Republic of Macedonia, 2018)

The values obtained for the weight of the harvest residues from the six most important crops (wheat, corn, barley, rice, rye and oats) which leave the largest amounts of harvest biomass, are calculated based on the harvest

index. The harvest index represents the ratio between the yield (the mass of the rest of the aboveground part of the plant at the time of harvest) and the yield (the mass of grain). In Table 2 is given the harvest index for some crops.

Table 2. Harvest index (harvest residue index/grain yield) for some crops.

Plant species	Harvest index (harvest residue index / grain yield)	Range – Grain Yield Rank* (kg/ha)
corn	1.0	3 100 – 9 400
soybeans	1.5	1 000 – 3 000
millet	1.0	2 500 – 5 600
winter wheat	1.7	1 700 – 4 000
spring wheat	1.3	1 700 – 4 000
spring oats	2.0	1 100 – 2 900

* If the grain yield is lower than the minimum value in the range, the index (harvest residue/grain yield) will need to be increased. If the yield is greater than the maximum value in the range, the index will need to be reduced

Source: McClellan et al., (2012)

The total annual production of corn grain, from all the municipalities in all regions was 19 000 tons (18 963 t, Tab. 1). The average amount of post-harvest residues which remains after the corn harvest, according to a large number of scientific studies, for the yield of 1 ton of corn grain, the same amount (1 ton) of stems and parts

of finished cobs remain as post-harvest residues. The largest amount (7 230 t) of corn post-harvest residue remains in the areas which were planted in Cesinovo – Oblesevo municipality. The least post-harvest corn residues (25 t) remain on the lands in Lozovo municipality.

Table 3. Barley and rice production by municipalities in the Bregalnica region in 2017.

Bregalnica region-municipalities	Barley				Rice			
	Area (ha)		Production		Area (ha)		Production	
	Sown area	Harvested area	Total t (tons)	Yield kg/ha	Sown area	Harvested area	Total t (tons)	Yield kg/ha
Berovo	130	130	215	1 650	-	-	-	-
Vinica	266	266	532	2 000	95	95	475	5 000
Delcevo	1 008	1 008	1 823	1 809	-	-	-	-
Zrnovci	343	336	841	2 502	158	158	736	4 657
Karbinci	1 077	1 017	989	972	318	150	941	6 270
Kocani	812	812	1 459	1 796	1 124	1 124	5 563	4 949
Lozovo	668	668	1 136	1 700	-	-	-	-
Makedonska kamenica	226	226	361	1 599	-	-	-	-
Pehcevo	121	121	281	2 323	-	-	-	-
Probitip	521	521	1 167	2 241	39	34	204	6 000
Sveti Nikole	3 049	3 049	3 211	1 053	-	-	-	-
Cesinovo - Oblesevo	834	834	1 495	1 793	1 713	1 713	9 162	5 349
Stip	1 182	1 182	853	722	6	-	-	-
Total ha/ t (tons)/ Average (kg/ha)	10 237	10 170	14 363	1 412	3 453	3 274	17 081	5 217

Source: Statistical Review: Agriculture (Statistical Office of the Republic of Macedonia, 2018)

The annual production of barley grain, from all municipalities in the region was 14 363 t (Tab. 3). The average amount of post-harvest residues remaining after barley harvest, for a yield of 1 ton of barley grain, on average about 1,7 t of straw remain as post-harvest residues, similar to wheat. The total average annual production of barley grain in the Bregalnica region was 14 363 t. When this will increase by 70% (1:1,7), on average, barley straw as a post-harvest residue remains about 25 000 tons (24 417 tons) in the territory of the Bregalnica region. The largest amount (5 459 tons) of post-harvest barley residues remains on the areas which were planted in Sveti Nikole municipality. The least post-harvested residues of barley crop (365 tons) remain on the lands in Berovo municipality.

In 2017, on an annual level, the total production of rice paddy in seven municipalities in which the rice is produced in the Bregalnica region was about 17 000 tons (17 081 tons, Tab. 3). If this amount is multiplied by the “post-harvest residues/grain yield” (0,75) the value of an average of 12 814 tons of rice straw post-harvest residue per year will be obtained. This value, as well as the values for the quantities of the other crops described so far, may vary from year to year, and in this paper, they are calculated according to the data for 2017. The largest amount (6 871 tons) of post-harvest residues of rice straw remains on the areas which were sown in Cesinovo – Oblesevo municipality. The least post-harvest residues from rice straw (153 tons) remain in Probistip lands.

Table 4. Rye and oats production by municipalities in the Bregalnica region in 2017.

Bregalnica region-municipalities	Rye				Oats			
	Area (ha)		Production		Area (ha)		Production	
	Sown area	Harvested area	Total t (tons)	Yield kg/ha	Sown area	Harvested area	Total t (tons)	Yield kg/ha
Berovo	870	870	2 443	2 808	120	120	138	1 146
Vinica	87	87	131	1 500	47	47	71	1 506
Delcevo	269	269	466	1 733	259	259	400	1 546
Zrnovci	10	10	19	1 850	3	3	5	1 667
Karbinci	-	-	-	-	15	14	9	671
Kocani	93	93	97	1 046	89	89	94	1 056
Lozovo	-	-	-	-	-	-	-	-
Makedonska kamenica	79	73	129	1 773	23	23	26	1 113
Pehcevo	350	350	976	2 789	100	100	115	1 145
Probistip	62	62	95	1 529	58	40	48	1 206
Sveti Nikole	61	61	85	1 401	-	-	-	-
Cesinovo - Oblesevo	10	10	17	1 740	3	3	5	1 500
Stip	11	11	7	609	15	15	8	511
Total ha/ t (tons)/ Average (kg/ha)	1 902	1 896	4 465	2 355	732	713	919	1 289

Source: Statistical Review: Agriculture (Statistical Office of the Republic of Macedonia, 2018)

The total annual production of rye grain in the Bregalnica region is amount of 4 465 tons (Tab. 4). According to the data of the Ministry of Agriculture, Forestry and Water Management, P.E Kocani, the index of “post-harvest residues/

grain yield” of cultivated rye plant, grown in the Bregalnica region was 1,7. In Bregalnica region, on average per year, the amount of 4 465 tons multiplied by the “post-harvest residue/grain yield” index (1,7) for rye, amounts 7 590 tons

of post-harvest rye straw residues. In Berovo municipality, the largest amount of post-harvest residues of rye straw was observed (4 136 tons). In 2017, the smallest amount of post-harvest rye straw residues (12 tons) was recorded in Stip municipality, while no rye was produced in Karbinci and Lozovo.

The oat is the least represented cereal crop grown in Bregalnica region and its annual grain production was 919 tons. According to several researches (Tab. 2), the index of "post-harvest

residues/grain yield" for the oat plant amount 2. The amount of 919 tons multiplied by the index of "post-harvest residues/grain yield" (2) for oat, amounts 1 838 tons post-harvest oat straw residues, on average per year in Bregalnica region. In Delcevo, the largest amount of post-harvest oat straw residues was recorded (800 tons), while the smallest amount (16 tons) was obtained in Stip municipality. In 2017, in Sveti Nikole and Lozovo, the oat crop was not cultivated.

Table 5. Average grain yield and "plant biomass after harvest" of some cereals grown in the Bregalnica region in 2017.

Plant species	average yield – grain (kg/ha)	average yield – plant biomass after harvest (kg/ha)
Wheat	1 622	2 760
Corn	4 740	4 740
Barley	1 412	2 400
Rice	5 217	3 900
Rye	2 355	4 000
Oats	1 289	2 580

Experiences and practices with the treatment of harvested biomass in the Bregalnica region

Certain unscrupulous growers mostly of rice knowingly break the law and decide on the unpopular agrotechnical measure of burning the after-harvest residues. For that activity they explain their purposes, reasons and justifications.

- PURPOSES: enabling the monocultural cultivation, that is, the non-implementation of the crop rotation;

- REASONS: farmers do the burning

Some harmful consequences of the burning of harvest residues

They are listed below according to the harmful consequences of burning post-harvest vegetable residues:

- significant net source of CH₄, CO, NO₂ and N₂O, which contributes to global warming, where CO and O₃ are indirect greenhouse gases;
- it has been scientifically proven that dioxin emissions increase 150 times when biomass treated with 2,4-D is burned;
- dioxin emission is between 35 and 270 times greater in the case of burning pesticide-treated corn crop residues, compared to the

because they don't have their own machinery – e.g., baling machines, the lack of manual labour or tractor loaders for loading and unloading the bales;

- JUSTIFICATIONS: destruction of: weed residues; plant residues from the previous crop, in order not to hinder the further cultivation of the soil; harvested crop residues and weeds infected with present residues of plant disease agents; destruction of eggs, larvae and eggs of insects – pests of cultivated crops.

amount of dioxin released when such crop residues are not treated;

- the increased pollution with suspended PM particles and sulphur dioxide (which are released into the atmosphere during the burning of rice straw);
- destruction of aboveground and underground beneficial flora and fauna - the temperatures that develop reach values of 200 to 400°C, and heat transfer entering at a depth of 5 to 20 cm in the soil has been recorded up to a critical 35 - 50°C, which is very harmful or lethal to the flora and fauna in the soil.

Alternatives for the application of agro-ecological activities for the usage of the harvest residues

The management of post-harvest residues from agricultural crops and the possibilities of applying agro-ecological measures, should be considered within a comprehensive view, integrating Best Management Practices – BMPs, in order to reduce the negative impacts that would be caused as a result of any improper treatments with the harvest residues. Integrating - Best Management Practices - BMPs - procedures that are increasing the sustainability of crop residues in the long term and including them in the replacing of the soil nutrients that are extracted with crop yield and residues - a cheap and ecological resource for improving soil

properties.

These practices usually include:

- reduced or minimal tillage of the soil,
- application of an appropriate crop rotation with the inclusion of cover crops, as well as the usage of organic fertilizers and siderites.
- Plant post-harvest residues can also be used for energy purposes:
- obtaining liquid and gaseous fuel (biogas and gas generating plants, pyrolysis technology and “fast” pyrolysis = bio-oil from rice straw through the fast pyrolysis process that are taking place in the special reactors in which the “flour” of finely ground rice straw is treated) and production of bioethanol and biodiesel
- processing into pellets or briquettes.

CONCLUDING REMARKS

The general one’s conclusions – recommendations for good agricultural practices for the management of harvest residues in the bregalnica region would be:

Prediction, organizing, directing and implementing activities in the direction of:

- designing and building processing capacity for the production of some of the products that can be obtained by processing harvested residues (compost, bio-oil, pellets, briquettes, biogas, etc.);
- organizing logistics (baling, loading, transport, unloading), i.e. through agricultural cooperatives;
- application of appropriate technologies for preparation and usage of rice straw and other types of plant residues for animal

feed, by enriching them with nitrogen, in order to improve the protein content and meet the requirements for proper animal nutrition;

- education of farmers with positive examples for the usage of the harvest residues (i.e. the usage of microbiological compounds that can accelerate the residues decomposition);
- modification and increasing of the subsidy values for the producers of compost, lumbrihumus, mushrooms and agropellets;
- maximum subsidy for the purchase of appropriate specialized agricultural machinery for mulching, baling, transporting (loaders, special trailers for transport), compost preparation machines, biodigesters, balers, etc.

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МОЖНОСТИ – АЛТЕРНАТИВИ ЗА ПРИМЕНА НА АГРОЕКОЛОШКИТЕ МЕРКИ И КОРИСТЕЊЕ НА ПОЖЕТВЕНИТЕ ОСТАТОЦИ

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Резиме

Во најголем број случаи стандардното одгледување на житните култури од страна на земјоделските производители се спроведува со примена на неодржливи на долг рок земјоделски практики. Особено третманот на пожетвените остатоци (најчесто палење на стрништата од ориз, пченица и јачмен), придонесува за зголемување на степенот на ризик од побрза и најчесто неповратна или многу бавно повратна деградација на природните ресурси.

Постапувањето со пожетвените остатоци задолжително треба да биде во согласност со стратегиите и практиките на добрата земјоделска пракса, кои се компатибилни со стратегијата на ЕУ во доменот на земјоделската политика. Само во Брегалничкиот Регион на годишно ниво на производните земјоделски оранични површини вкупно остануваат околу 100 000 тони (96 082 тони) „пожетвени остатоци“. Овие количини се добиваат од вкупно околу 31 100 хектари оранична површина на која се одгледуваат најзастапените житни култури (пченица, пченка, јачмен, ориз, ‘рж и овес). Просечно од сите култури на годишно ниво остануваат по околу 3,2 t/ha пожетвена надземна растителна биомаса, што претставува значаен ресурс кој најчесто се искористува нерационално, а понекогаш и штетно за околината од страна на земјоделските производители.

Анализирана е праксата на земјоделските производители на жита и предложени се алтернативни пристапи за користење на пожетвените остатоци. Потенцирани се дополнителните финансиски импликации кај фармерите кои можат да ги остварат со правилен третман на пожетвените остатоци. Образложени се предлог-мерки и активности за одржливо управување со растителните остатоци по жетвата.

Клучни зборови: жита, земјоделски практики, деградација, одржливо управување.