FLOODS AND THEIR EFFECTS ON AGRICULTURAL PRODUCTIVITY

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Abstract. *Romania is located in a temperate-continental climate zone with a moderate precipitation regime, but in recent years, as a result of climate change, there have been significant deviations from the average annual values of temperature and precipitation compared to the multiannual average values, both in Europe and around the world. Agriculture and agricultural productivity suffer a negative impact generated by climate change and extreme weather phenomena, which is added to the negative influence of the anthropogenic factor that causes the intensification of these phenomena through greenhouse gas emissions, deforestation, land waterproofing as a result of the expansion of residential areas, etc. The consequences of the floods affect the level and variability of agricultural production, affect the management of livestock, as well as the location of production as an agro-climatic zone, registering a transition to higher lands. These effects can jeopardize the supply of food on the internal market in some parts of Europe, also leading to increased price instability and an increased risk to farmer's incomes. At the level of Romania, severe localized phenomena were registered, such as prolonged drought, violent storms, large hailstorms, or extreme precipitation from a quantitative point of view, which led to the occurrence of numerous cases of floods. The succession of mentioned phenomena in recent years has demonstrated the country's vulnerability to extreme conditions. The evolution of the average annual precipitations in Romania in 2018 indicates deviations from the climatological norm in force (multiannual average for the 1981-2010 period) at many meteorological stations in the country. The paper presents a brief synthesis of the precipitation regime in Romania, respectively a case study on the floods produced in 2018 and an analysis of their effects on the agricultural sector from a productive point of view. The work ends with a series of solutions and measures to prevent floods in vulnerable areas.*

Keywords*: floods, causes, effects, crops, agricultural productivity*

INTRODUCTION

Floods are natural phenomena that consist of temporary water cover of land. Floods, normal manifestations in the water cycle, result from the heterogeneity that characterizes the location, intensity, and duration of rains over time, being some of the most common extreme phenomena globally.

Floods affect many economic sectors, and agriculture is one of the most exposed, as agricultural activities depend directly on climatic factors. This is important for Europe because almost 50% of its area is agricultural land. (PERPIÑA ET AL., 2018). Adaptation is a critical challenge for agriculture.

Floods cause massive damage to crops. In 2009, in the southern areas of the Irkutsk region, almost all potato plantations were affected by a fungal disease, with 90% yield losses. As a result of river overflows, even plants became unsuitable for animals because the surface of the leaves was covered with mud. (PROSKURA AND TKACHENKO, 2013)

Climate change is an aggravating factor, leading to changes in rainfall and weather patterns, rising sea levels, and, as a result, more frequent and more severe floods. Agriculture itself contributes to climate change by increasing the greenhouse effect (due to greenhouse gas emissions). Approximately 5% of total N_2O emissions come from the application of organic and mineral nitrogen fertilizers, and almost 4% from CH_4, mainly from the digestive processes of ruminant animals and, to a lesser extent, from manure deposits. (ZĂVOIANU, 2009; LAZĂR AND DUMITRESCU, 2006; LAZĂR AND FAUR, 2011)

In this diverse climate, there are many problems, from difficulties in adapting to new conditions of plants and animals (the advantage of animal species being their mobility) to improper development of crops and severe damage in terms of quantity and quality of the harvests, from the increase of the prices of the agricultural products to the lack of food sources and the lack of incomes, or even hunger etc.

The consequences of the increasing frequency of extreme weather events such as hail, heavy rainfall, storms, heatwaves, and drought are being felt all over Europe. Their succession in recent years has demonstrated Europe's vulnerability to extreme conditions, and experts say their frequency could increase. The risk of floods in Central and Northern Europe is increasing. In recent years, in Romania, floods have caused great material loss and even life losses. (PASQUI AND GIUSEPPE, 2019)

MATERIAL AND METHODS

Atmospheric precipitation is any form of water (rain, drizzle, frozen rain, snow, sleet, hail, peas, frost, dew etc.) that falls from the atmosphere on the ground. Precipitation is a basic component of the water circuit in nature. They arise when the raindrops reach the required size (0.5-0.6 mm) to overcome the upward currents and submit to the force of gravity. The process of forming raindrops is the combined result of two main phenomena, namely: condensation of water vapor on the surfaces of water drops or ice crystals in the cloud mass and merging several smaller drops into a larger one. (ROTUNJANU AND LAZĂR, 2014)

The precipitation regime in Romania

Romania is located in a temperate-continental climate zone with a moderate rainfall regime. The amount of average annual rainfall varies depending on two main factors: latitude and altitude. The precipitation in Romania is moderate, the average annual rainfall in the country being of 637 mm. The average annual rainfall in the plain area varies between 400 mm in Dobrogea, 500 mm in the Romanian Plain, and up to 600 mm in the Western Plain. As the altitude increases, the amount of precipitation also increases, reaching values of up to 1000 - 1200 mm/year at altitudes higher than 1800 m (Figure 1).

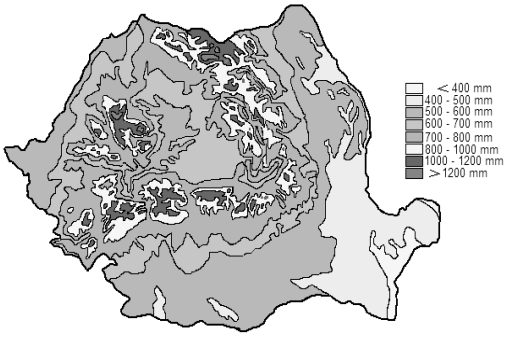

Figure 1. Map of average annual rainfall in Romania (ANM, 2018)

Locally, lower or higher amounts of precipitation can be recorded. The highest amounts of precipitation are recorded in the hot season, especially in the form of heavy rain, predominant being the convective type. In mountain areas, orographic precipitation predominates. In winter, precipitations are usually of frontal type, due to the activity of mobile cyclones, the frequency of snow is high, and the snow layer is thick and persistent for a long time. (NIMARĂ, 2016)

According to data published by the National Meteorological Administration (ANM, 2018), on the background of global climate change, there have been significant deviations of the rainfall and thermal regimes of Romania. Thus, in the last century, there has been a gradual warming of the atmosphere, as well as a significant reduction in rainfall.

According to a press release of the Ministry of Environment of Romania, 2018 was the third warmest year since 1901, with an annual average air temperature of 11.57°C, which exceeds by 1.35°C the current climate norm (multiannual average between 1981-2010). Analyzing the top of the hottest ten years from 1900–2018, it was noticed that nine of them belong to the period 2000–2018. (MINISTRY OF ENVIRONMENT, 2019)

Thermal regime anomalies also affect the precipitation regime. The average annual amount of precipitation in 2018 was 698.3 mm, registering an exceedance of approximately 10% of the climatological norm in force. The deviation of the monthly amount of precipitation was positive in 6 of the 12 months of 2018, and in the rest of the months, there were negative deviations (Table 1).

Table 1

The climatological norm in force (1981 – 2010) and the evolution of average monthly amount of precipitation in 2018 (ANM, 2018)

	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1981-2010	33.6	31.6	38.3	51.3	66.5	84.5	77.8	64.7	55.0	43.5	41.5	44.8
2018	39.1	55.1	73.3	18.2	56.7	158.8	119.3	32.2	27.0	20.0	39.3	59.3
Deviation (mm)	5.5	23.5	35.0	-33.1	-9.8	74.3	41.4	-32.5	-28.0	-23.5	-2.2	14.5
Deviation (%)	16.37	74.37	91.38	64.52	14.74	87.93	53.34	50.23	50.91	54.02	5.3	32.37

positive deviations; negative deviations

The positive deviations varied between 16% and 92%. The most significant positive deviations were registered as follows: February with 74.37%, March with 91.38%, June with 87.92%, and July with 53.34%, while the negative deviations ranged between 6% and 65%. The most significant negative deviations were registered as follows: April with 64.52%, August and September with about 50%, and October with 54.02%.

In the previous year (2017), the average annual amount of precipitation was 673.5 mm, registering an exceedance of approximately 6% of the climatological norm. (ANM, 2017)

Factors and causes of floods

Floods vary in frequency, location, and intensity due to seasonal and regional variations in rainfall, other weather events, and long-term climate change.

Flooding is caused by a number of climatic factors that generate large amounts of water, such as heavy rainfall (torrential rains) or the sudden melting of snow or ice which leads to water overflows (streams, rivers, lakes, etc.).

The anthropogenic factor also influences the production of floods by:

- industrial activities resulting in greenhouse gas emissions. Greenhouse gas emissions accentuate the greenhouse effect, which is the main cause of global warming and climate change. Greenhouse gases include water vapor resulting from various combustion processes. As a result of the increase of the global average temperature, the evaporation process intensifies, and together with the water vapor resulting from the combustion processes, it determines changes in the precipitation regime;

- massive deforestation in mountain areas accelerates the phenomenon of surface runoff, therefore the risk of flooding increases;
- waterproofing of lands as a result of the development of residential areas;
- urban development in areas where flooding risk exist can lead to the intensification of the negative effects in those areas;
- the development of agriculture in floodplains can lead to significant losses in agricultural productivity;
- hydrographic arrangements. Breaking dams can increase the risk of flooding in downstream areas.

Effects of flooding

Floods can be divided into 2 categories:

• floods produced in the lower and middle courses of the rivers (plain floods). They occur especially in the case of long-term precipitation. The waters overflow and invade the major riverbed. The water level rises progressively, being determined by the intensity of the rains as well as by the configuration of the hydrogeographic network.

• floods produced in the upper courses of rivers (floods in mountain areas). They occur as a result of relatively short but heavy rainfall. The water level rises quickly (flash flood) and large amounts of solid materials are often transported.

The effects of the floods are noticeable as negative, but although it seems hard to believe, the effects of the floods can also be positive. (АПАТОВА ET AL., 2001):

1. The negative effects of floods are felt especially in areas where local communities have developed or in the case of productive lands. Negative effects of floods include:

- injuries and life losses;
- material losses and considerable economic costs, mentioning here the damage caused to crops;
- water saturation of the soil and subsoil and damage to crops;
- leaching nutrients from soils;
- damage to the environment and cultural heritage.

2. The positive or beneficial effects of floods consist of:

- the large supply of water which leads to the recharging of river courses, surface reservoirs (lakes) and underground aquifers;
- soil fertilization due to the proliferation of microscopic freshwater algae that fix nitrogen in flooded areas;
- improving the quality of downstream waters by retaining many pollutants by plants and soils of alluvial plains that are a natural filter.

RESULTS AND DISCUSSIONS

Romania is relatively frequently affected by floods and their negative effects. Despite the execution of numerous hydro-technical works designed to reduce peak flows, floods continue to be present, causing great material damage and loss of life.

Floods. Case study: Romania 2018

In the context of meteorological warnings of heavy rainfall, hydrologists have issued flood warnings in many river basins in the country. Among the phenomena forecasted and subsequently manifested are significant surface runoff, torrents, rapid floods on streams and small rivers with local floods and increased inflows and levels on rivers with possible exceedances of defense quotas, to which is added the melting of snow in February - March. (INHGA, 2018)

Agriculture is among the sectors with the highest losses. At the national level, according to existing data (INS, 2019), the total agricultural area (arable, pastures, hayfields, vineyards and vine nurseries, orchards and tree nurseries) is about 15 million hectares, registering relatively small decreases or increases from one year to another.

As a result of the heavy rainfall in February and March and the melting of the snow, several streams and rivers in the country overflowed and flooded dozens of hectares of agricultural land and pastures (Figures 2.a - b). In the summer of 2018, more precisely in late June and early July, due to heavy rainfall, there were floods in many areas of the country, the effects of floods consisting mainly of material destruction, flooding tens of thousands of hectares of agricultural land and pastures, but there were also losses of human lives (Figures 2.c - e).

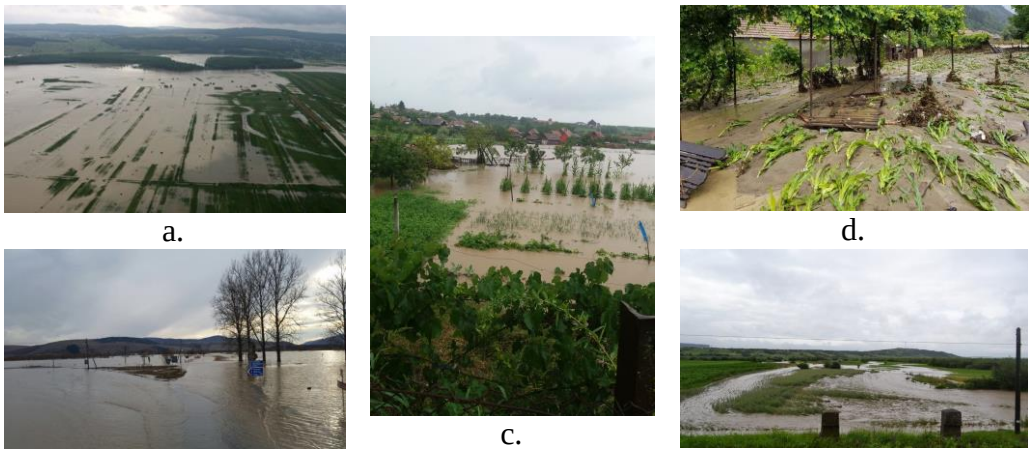

Figure 2. Flooded agricultural lands;
a. overflow of the Târnava Mare river (ISU ALBA, 2018); b. overflow of Cormoș stream (ISU COVASNA, 2018); c. floods in Bucerdea Granoasa Commune, Alba County; d. individual households and agricultural land affected by floods in Bacău County (ISU BACĂU, 2018); e. agricultural land affected by floods in Suceava County (ISU SUCEAVA, 2018).

Localities from over 20 counties have faced these phenomena, being severely affected by floods. Agricultural land belonging to individual households has also been affected, and the damage is being strongly felt by them.

Identifying the effects of floods on agriculture

To identify the effects generated by floods on agriculture, the network method was applied (Figure 3). This method is recommended to study the cause-effect relationship.

A network consists of flow charts or chains of multiple relationships and allows the identification of chains of direct and indirect, primary and secondary impacts/effects generated by an action or phenomenon that generates a certain impact/effect. (LAZAR AND DUMITRESCU, 2006; LAZAR AND FAUR, 2011)

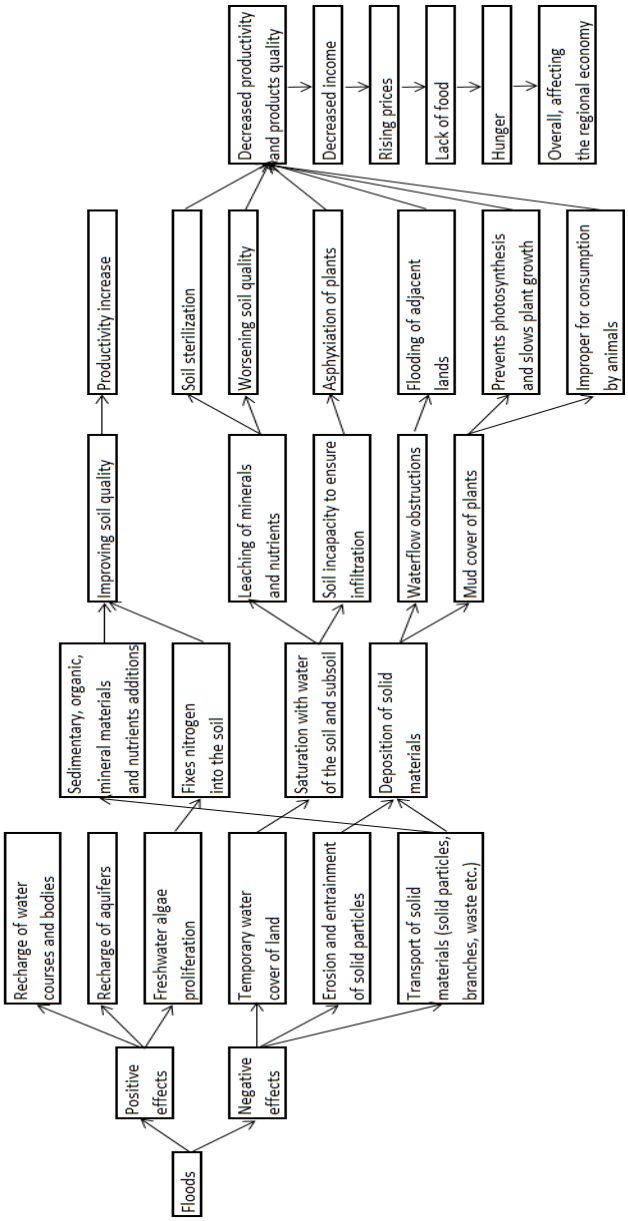

Figure 3. Network for identifying the effects of floods on agricultural productivity

As can be seen in Figure 3, the effects of floods can be both positive, leading to an improvement in soil quality and productivity due to the supply of surface and groundwater sources and the intake of organic matter, mineral, and nutrient salts, and negative, these being felt by lower productivity, rising prices, declining producer incomes, lack of food and even hunger, especially in subsistence farmers and affecting the regional economy as a result of

worsening soil quality (washing nutrients from the soil, depositing solids on the ground and plants), the inability of the soil to ensure water infiltration, the suffocation of plants etc.

Agricultural productivity at national level

The floods have caused significant damage to agricultural producers, especially to subsistence farmers, in the context in which tens of thousands of hectares of agricultural land have been flooded, crops being compromised. Among the most affected agricultural crops are wheat, rye, oats, corn, rapeseed, but the effects on vegetable and fruit crops cannot be neglected either.

Taking into account the temporal location of floods (February, March, June, July 2018) the assessment of agricultural productivity was based on crops of wheat, rye, oats, rape, corn, autumn potatoes, tomatoes, peppers, white cabbage and grapes. Table 2 shows the average production (in kilograms/hectares) of the mentioned crops.

Table 2

Average production of different types of agricultural products (INS, 2019)

Crops	2013	2014	2015	2016	2017	2018
	kg/ha					
Wheat	3468	3590	3780	3944	4888	4793
Rye	2217	2396	2532	2479	2937	2790
Oat	2051	2124	1999	2239	2460	2376
Rape	2408	2604	2499	2835	2798	2546
Corn grain	4488	4770	3462	4159	5959	7644
Autumn potatoes	16234	17888	13759	14635	18759	18081
Tomatoes	15488	16102	15857	15297	16978	18235
Green peppers	11682	12531	12289	11224	12759	12775
White cabbage	21062	23478	22127	21458	22220	22513
Grapes	5559	4436	4484	4136	6020	6447

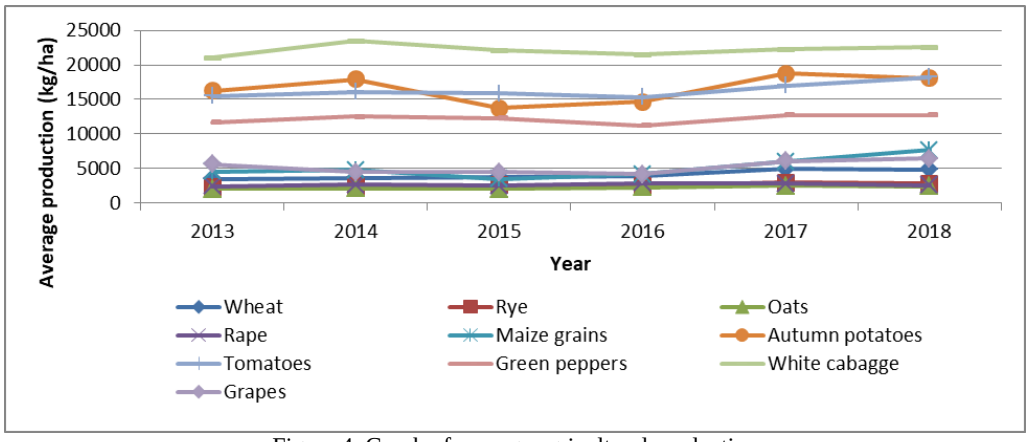

Figure 4. Graph of average agricultural production

Analyzing the data in Table 3 and the graph in Figure 4 showing the average production of crops proposed for analysis, it is found that 2018 is not marked by a worrying decline in production due to floods this year. On the contrary, a worrying decrease can be observed in 2015 due to severe droughts. High temperatures and atmospheric and pedological drought have had a negative effect on the primary agricultural production sector, with many crops being affected by more than 30%. (GOVERNMENT OF ROMANIA, 2015). A low production

is also observed in 2016, when several dry periods were registered which manifested themselves with different intensities throughout the country.

The lack of data at the regional level obstructed a more detailed study in order to highlight the negative effect of floods on agricultural productivity. Considering the available data, their processing was performed in order to compare the average production corresponding to 2018 with the average production of the previous year, respectively with the average production for the 2013 - 2017 period. The results are shown in Table 3.

Table 3

The average production of 2018 compared to the previous year and compared to the average production for the 2013-2017 period (INS, 2019)

Crops	Average production						
	2013-2017 period	2017	2018	of 2018 compared to the average of the previous 5 years		of 2018 compared to the average of the previous year	
	kg/ha				%	kg/ha	%
Wheat	3934	4888	4793	+859	+21.84	-95	-1.94
Rye	2512.2	2937	2790	+277.8	+11.06	-147	-5.01
Oat	2174.6	2460	2376	+201.4	+9.26	-84	-3.41
Rape	2628.8	2798	2546	-82.8	-3.15	-252	-9.01
Corn grain	4567.6	5959	7644	+3076.4	+67.35	+1685	+28.28
Autumn potatoes	16255	18759	18081	+1826	+11.23	-678	-3.61
Tomatoes	15944.4	16978	18235	+2290.6	+14.37	+1257	+7.40
Green peppers	12097	12759	12775	+678	+5.605	+16	+0.13
White cabbage	22069	22220	22513	+444	+2.012	+293	+1.32
Grapes	4927	6020	6447	+1520	+30.85	+427	+7.09

Compared to the average production of the previous 5 years (2013-2017), the average production of 2018, increased in almost all cases (of 2 to 67%), except for rape, which registered a decrease of 3.15%. Compared to the previous year, the results indicate a decrease in average production in 2018 in the case of cereals, rape, and autumn potatoes (of 2 to 9%), the largest decrease being registered in the case of rape. In the other cases, compared to the previous year, there is an increase in productivity, especially for corn grains (of 28%), tomatoes (of 7%), and grapes (of 7%), possibly due to the 2018's rainfall and floods, which do not seem to have been destructive, but rather were favorable for these crops.

The decrease in productivity registered in 2018 compared to 2017 can be explained by the higher amount of rainfall in 2018 (by 4% compared to 2017) and their regional and temporal distribution. Higher rainfall in early 2018 compared to 2017 (when there were negative deviations in January and March and positive deviations in February of 2%, but insufficient to cover the previous month's deficit and to ensure the following deficit) and the floods produced as a result of these precipitations, can represent the cause of the decrease of the productivity of cereals, rape, and autumn potatoes. Sowing in these crops takes place in autumn (wheat, rye, rape, autumn potatoes) and early spring (oats), and the conditions offered by excessive rainfall seem to have had a negative effect on agricultural productivity. Despite all fears, agricultural productivity at the national level has not been severely affected, but the negative effects of the floods have been felt strongly in subsistence agriculture. Subsistence agriculture is particularly affected because it has lower adaptability. This can increase the risk of hunger, given that their own production is the only food source for some farmers.

Measures to prevent flooding

Flood risk management means the application of policies, procedures, and practices aimed at identifying risks, analyzing and assessing them, treating, monitoring, and reassessing

risks in order to reduce them so that human communities, can live, work, and meets the needs and aspirations in a sustainable physical and social environment.

The European Union has adopted the Flood Risk Assessment and Management Directive to coordinate flood prevention, protection, and training, both within each Member State and between the Member States, at the river basin level. Floods are best managed at the river basin level, where there are a number of measures that limit leakage, slow down river flows, allow flooding to spread on natural and agricultural land, protect vulnerable assets, and do not aggravate downstream floods, in accordance with Directive on floods. (***, DIRECTIVE 2007/60/EC, 2007; ECA, 2018).

Green infrastructure (consisting of floodplains, wetlands, or river meandering) and gray infrastructure (traditional flood protection solutions such as dams, channels, installations, and other defense barriers) can be used in combination to reduce problems related to floods. In addition, the degree of exposure of the population and property to floods can be reduced through rational land use planning, population awareness activities, and property insurance.

The following measures are recommended for protection against floods:

- avoiding the construction of houses and social, cultural and/or economic objects in the potentially floodable areas of the major riverbeds;
- promoting adequate land use practices;
- control of the use of minor riverbeds;
- carrying out works designed to reduce the surface runoff (reforestation or afforestation, construction of torrents retention basins);
- the geographical delimitation of the natural risk areas for floods;
- implementation of forecasting, warning, and alarm systems for flood cases;
- creation and maintenance of existing flood and riverbed protection infrastructures;
- educating the population about the risk of floods and how to act in emergency situations.

CONCLUSIONS

Floods are normal phenomena, so it is natural for the waters to invade the major riverbeds in periods of heavy rainfall. Special problems arise in situations where anthropogenic objectives (roads, rural and urban agglomerations, industrial objectives) and productive land are located in these areas at risk of flooding.

Floods can have both positive and negative effects on agriculture. The positive effects consist of increased productivity due to the improvement of the soil quality, recharge of the aquifers and surface watercourses and bodies, intake of organic matter, mineral, and nutrient salts. The negative effects determine the decrease of productivity, the increase in the prices of agricultural products, declining producer incomes, lack of food, and even hunger, especially in subsistence farmers. The regional economy can be seriously affected. The negative effects of floods on agriculture result from: worsening soil quality (washing nutrients from the soil, depositing solids on the ground and plants), the inability of the soil to ensure water infiltration, the suffocation of plants etc.

The result of the study showed that floods that occurred in Romania in 2018 did not affect, in a worrying way, the agricultural productivity at the national level (as it happened in the case of the drought of 2015). The average production of 2018:

- increased in almost all cases (of up to 67%), except for rape (registering a decrease of 3.15%), compared to the average production of the 2013-2017 period;
- increased in more than half of the analyzed crops compared to the previous year, possibly due to the climatic conditions which seem to be favorable for this type of crops; high increases (of up to 28%) were registered in the case of corn grains, tomatoes and grapes;

- decreased in the case of cereals, rape, and autumn potatoes (of 2 to 9%; highest decrease was registered in the case of rape), compared to the previous year, as a result of higher amount of rainfall in 2018 (by 4% higher compared to 2017), floods and their regional and temporal distribution.

The climatic conditions of 2018 (excessive rainfall san floods) seem to have had a negative effect on agricultural productivity. However, the negative effects of the floods have been felt strongly in subsistence agriculture as a result of the lower adaptability of the small crops.

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