Role of Riparian Zones in Reducing Pollution of Surface and Ground Water, Increase Agricultural Production and Nutrient Acquisition and Storage in River Catchments

Iuliana Florentina Gheorghe, Daniela Strat, and Simona Mihailescu

Abstract Romania is a country relatively poor in water resources: almost 75 000 millions m^3 from which 67 000 millions m^3 surface water and 8000 millions m^3 ground water. Half of the surface water (68%) of Romania is of the first quality, while degraded water represents only about 11% of the whole volume. The average amount of water used in Romania annually is of ca. 9.051 billions m^3, of which: industry 4.823, domestic 2.887, agriculture 1.299 and others 0.042. Irrigation in Romania is fully controlled. Nutrients input of from agriculture into the surface waters by percolation from the soil in river basins is high, majority of domestically wastewater (74%) are not collected and treated [1]. Riparian zones are an important role in nutrient acquisition and storage reducing pollution of surface water, ground water and increase agricultural production. In river catchment a green infrastructure with lakes and rivers, wetland, different types of forest, pastures, shrubs including different types of crops, it represent the ideal structure to harmonize the development and nature conservation. Plants have limited ability in uptake and storing nutrients, and storage time is different, finally the nutrients reach the litter that is decomposed. Decomposition and the nutrient cycles are fundamental to ecosystem biomass production. Most natural ecosystems are nitrogen (N) limited and biomass production is closely correlated with N turnover [2, 3]. In natural ecosystems, external input of nutrients is very low and efficient recycling of nutrients maintains productivity [4]. This chapter presents the effectiveness of different types of riparian zone in nutrient acquisition and storage with a role in reducing pollution of surface water, ground water and increase agricultural production.

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1 Introduction

Romania is relatively poor in water resources: almost 75 000 millions m^3 from which 67 000 millions m^3 surface water and 8000 millions m^3 ground water. The specific water resource is 3246 m^3/inhabitant/year, of which 1650 m^3/inhabitant/year come from Danube River. At national level the diffuse and point pollution sources are uniformly distributed and polluted water increases the costs of treatment of its. More than half (68%) of the surface water of Romania is of the first quality class, while degraded water represents only about one tenth (11%) of the whole volume. The average amount of water used in Romania annually is of 9.051 billion m^3, of which: the industry is using 4.823, the housing 2.887, the agriculture 1.299 and others 0.042 [1]. After 1989, the trend, in agricultural irrigation water using, is a decreasing one due to both reductions of the irrigated area and to dismantling of the huge industrial complexes of livestock breeding. Waste water use in irrigation is still very limited, on one side due to the reduced facilities for treatment, but mostly because surface water and ground water resources are enough to satisfy the needs of the areas that are prone to irrigation. Keeping a good water quality and an increase of agricultural production in Romania is an important need for political, economical, moral and scientific reasons. The political reason is that Romania is a member of European Union and it must to respect European legislation, meaning the Water Framework Directive objectives in the field of water conservation policy. The aim of directive is to establish a framework for the protection of intern surface waters, transitional waters, coastal waters and groundwater. The most important moral reason is the water quality. A good water quality in sufficient quantity influences the health condition of the people. The preservation of riparian zone (the interface between land and a river or a stream), and aquatic ecosystems is also a very important scientific and economical reason due to a lot of natural resources produced by these complex ecosystems, including a good water quality. Agriculture and housing wastewater represent two type of pollution source with nutrients. Riparian areas can help as buffer zones and reduce (retention, remove) the effects of non-point source pollution, riparian areas play a key-role in the nutrients flux. Unfortunately, when the buffer zone capacity has been exceeded a very large amount of nutrients is discharged in the river water, for this reason we must to know the buffer zones capacity to stock the nutrients. Nutrient availability in water and soil is highly heterogeneous in space and time. Consequently, efficient growth up of vegetation and uptake of nutrient can be strongly influenced by the ability of the roots system that constantly it does develop, and it’s most absorptive elements in the most favorable soil, temperature and humidity [5]. One of the major global issues particularly at European level is the use of fertilizers in agriculture. On the one hand the need for food requires the use of a surplus of nutrients with role in increase in agricultural production, on another part, the excess use of these nutrients leads to soil degradation and pollution of ground water and surface water. Agriculture, previously dominated by productivity, now has multiple objectives. The crops low environmental impact, the quality of crop products, the low cost of production and hence increased nutrients use efficiency, are among these objectives. Understanding the processes that govern nutrient fluxes, particularly nutrients uptake and distribution in crops, is of major importance with respect to both environmental concerns and the quality of crop products [6].

2 Water Resources of Romania

Romania occupies approximately 29% of the Danube basin area (Fig. 1, Table 1) the total length of rivers is 78,905 km, total volume - 40 billions m^3, and almost 1,840 m^3/inhabitant.

Almost all-surface water resources originate from the inland rivers and from the Danube. The average multiannual volume of inland waters amount to an of 42,293 millions m^3, where the largest share is held by the Siret (17%), Mures (13.8%) and Olt (13%) rivers.

Fig. 1 Maps of the Danube River Basin District [8]

Table 1 The hydrologic network capacity in Romania

Source	Total capacity (millions m^3)	Potential used capacity (millions m^3)	Capacity used (millions m^3)	Percent of total use %
Interiors rivers	40.000.000	13.059.071	3.940.724	9.85
Danube river	85.000.000	20.000.000	4.737.664	5.57
Ground waters	9.600.000	6.677.150	758.628	7.9

At the inlet into the country, the Danube's multiannual input is of 175,598 millions m^3. The water resources of Danube are also available to the neighboring countries (Yugoslavia, Bulgaria and Ukraine). The Romanian share from the Danube waters is estimated to 85 000 millions m^3 [1, 7].

In years with normal droughty, the total flow by the inland rivers is almost 29 658 millions m^3 and represent just 70% of the mean multiannual volume that is 42 293 millions $m^{3.}$ During a year with accentuated droughts the total flow is 22 309 millions m^3 and represent just 52.7% of the multiannual one. The Danube displays a different regime. The contribution of the tributaries from the Alps region preserves the flow along the river at a high level even during years with high droughty this being between 84 and 72% of the multiannual flow [7].

On the surface of Romania there are 11 hydrographic basins of relatively equal size, the largest being of the Siret river (42,890 km^2) and the smallest Dobrogea - Litoral (5,480 km^2) (Table 2).

The most populated basin is the basin of Argeş - Vedea River with a relatively small surface (21,847 Km^2). It is one of the most vulnerable the river basin regarding nutrient pollution and represents the ideal case study for following study.

3 Geography Description of River Basin

The Argeş-Vedea catchment lies on central part of the Romanian Plain. This major landform unit is located on the left side of the Danube River where it is the border between Romania and Bulgaria. Tectonically, the Romanian Plain has developed on the northern part of Moesian Platform, over which overlaps a thick sedimentary cover [9].

The most recent deposits consist of loess and loess-like deposits, dominantly composed by silty clay [10–12]. Beneath them are gravels and sands of lower Pleistocene ages [9] that represent a phreatic stratum which host valuable groundwater resources. Along the river valleys, the alluvial deposits are composed by fine gravels, sands and clay. The most distinctive landforms of the Argeş-Vedea catchment are the tabular interfluves, which have been shaped by the rivers network. The altitudes slightly decrease from north to south, ranging from 180 to 50 m. Slopes are nearly level and very gentle, with a mean value of slopes of 1°. These morphologic and morphometric features of this lowland area are key drivers for rivers meandering. Different

Table 2 Human activities, population density in all 11 river basins present at national level

Name of catchments	Surface area (km^2)	Number of inhabitants	Number of city and villages	Industry	Houses
1. Someş-Tisa	22,380	2 090,000	243	722	37,200
2. Crişuri	14,860	1 282,800	195	175	80,477
3. Mureş	27,890	2 190,000	238	381	60,167
4. Banat	18,320	3 640,000	349	415	69,213
5. Jiu	18,975	1 638,900	179	122	5,937
6. Olt	24,050	2 676,000	245	154	4,376
7. Argeş-Vedea	21,847	3 942,500	180	457	24,228
8. Buzău-Ialomiţa	26,205	2 604,000	209	220	22,457
9. Dobrogea-Litoral	5,480	680,000	13	-	-
10. Siret	42,890	2 792,400	143	328	17,793
11. Prut	20,680	1 821,000	193	210	14,306

generations of old meanders of Argeş-Vedea River can be identified and oxbow lakes occur in the flood plain. The wide of flood plain ranges from about 100 to 500 m.

Based on geographical location and altitudinal values, in the area of Argeş-Vedea catchment there is a temperate continental climate, with cold winters hot summers, huge range of extreme temperatures and quite equal distribution of rainfall per seasons. With a mean annual sunshine duration of 2254 h, the mean annual air temperature is 11.1 °C and the annual amount of precipitation is about 532 mm for the period 1961–2013. The mean air temperature of January, the coldest month, is below 0 °C but the annual number of *air frost days fluctuates from 100 to 120.* During the summer, the mean air temperature in July is around 23 °C; the mean maximum is 32 °C and de annual number of days with mean air temperature over 30 °C is around [13]. The degree of continentality of the climate in the study area is depicted by value of the Johansson *Continentality Index* that is 44.6, which means a continental climate [14, 15]. For the same time period, in terms of the annual De Martonne aridity Index (25.2), the climate can be described as a semi-humid one. Annually, potential evapo-transpiration (PET) varies between 598 and 718 mm, surpassing the yearly precipitation, but during the winter (December - February) the PET value is 0 mm, while the highest values are calculated during the summer months, June–August, with an average that range between 143/month and 147 mm/month, much higher than precipitation amount (Fig. 2).

As a result, during the growing season and especially during the summer months there is water deficit. Regarding nebulosity, during the whole year, on average there are 135 clear sky days, with those of 117 cloudy sky and the sky covered with those of 123. During the study period (2008–2013), the average annual air temperature in the sampled catchment area was higher (11.9 °C) that in 1961–2013 period and the amount of precipitations was 529.6 mm. Rainfalls were distributed almost equally, but in terms of quantity, the summer is the rainiest season (117.7 mm) with the peak precipitations in June. Figure 3 depicts the temperature-precipitation diagram

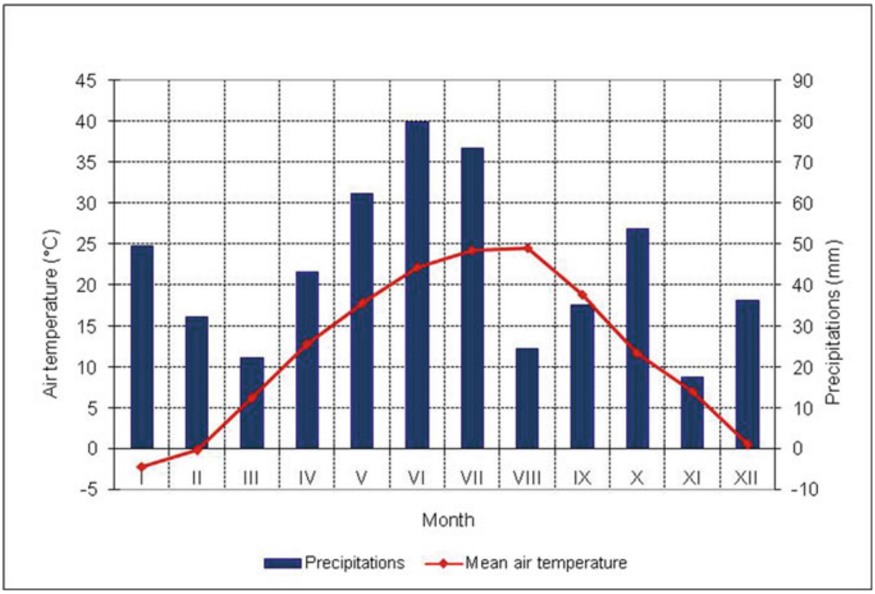

Fig. 2 The monthly air temperature –precipitation diagram during 2008–2013 in the Argeş-Vedea catchment

at the meteorological station that is located at the central-western part of the Argeş-Vedea catchment. The climate diagram shows that only two months—August and September are characterized as climatic arid according to Gaussen classification.

However, the value of the summer drought index, calculated as the ratio between summer precipitation amount and mean maximum air temperature of the hottest month [16], that is 5.3, emphasizes that in the study area the summers are droughty. The annual De Martonne index was 24.1, which depicts a semi-humid climate but compared to the multiannual value (1961–2013) it is a threshold change, from forest steppe, previously, to steppe grassland during the study period time. The mean distribution of the monthly De Martonne aridity index shows the maximum climate diversity—all seven climate types (Fig. 3), according to De Martonne classification [17, 18], from extremely humid, in January, to arid, in August. The greatest diversity of climate types is during summer because each month has different characteristics, humid, semi-humid and arid respectively. Overall, De Martonne aridity index value was 21, which correspond to the Mediterranean climate.

According to climate conditions and natural vegetation, in the area are developed fertile soils that belong tochernozem types and red brown main types respectively with the following particular subtypes: typical red brown, luvicverticred brown, luvicpseudogleyed red brown, gleyed red brown, gleycpodzolicchernozem-like soils, and leached chernozem.

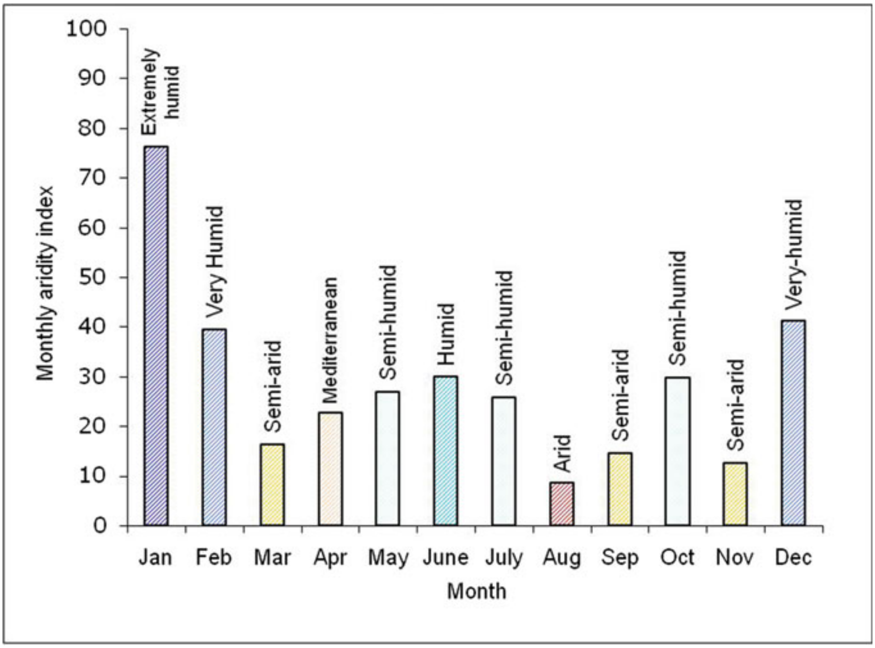

Fig. 3 The monthly distribution of the mean of De Martonne aridity index, from 2008 to 2013 in the Argeş-Vedea catchment

4 Land Use

About About ¾ of the Argeş-Vedea catchment (as the other river basins present in the Romanian Plain) area is covered with agricultural land (72.5%), this is followed by the land covered with various constructions, (13%), it represent the rural areas and consists of villages. The forests occupy 12% of the territory, wetland 2%, rivers and lakes 0.5% (Fig. 4). Although the forest area is not very large there is a great diversity of temperate continental types of forest. Dominant tree species are of the genera Quercus, Salix, Populus, Alnus, Acer, Ulmus, Fraxinus, etc. [19, 20] https://www.ijese.org/download/volume-2-issue-5/.

22.4% of this field is present in the riparian zone and covered with these types of vegetation: wetland with Carex sp. *Lythrum* sp. *Scyrpus* sp.; wetland with *Salix* sp. *Phragmites* and *Typha* sp., *Scyrpus* sp.; pastures; meadows, grasslands, orchards; forest (24 typologies); crops: wheat (81%), sunflower (3%), maize (11%), rape (5%) (Table 3).

For maps of land use were used digitized maps “Corine land cover 2006”, being processed in the ArcView GIS 3.2 a, example Fig. 5,

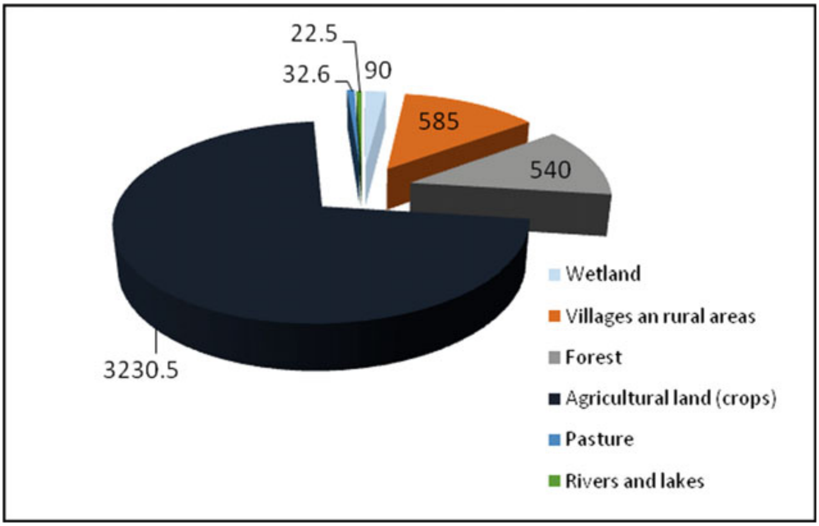

Fig. 4 Type of land cover at catchment level (ha)

Table 3 Types of riparian zones in rivers catchments

Structure of riparian zone	Dominant species plants	Longer (km)	Surface (ha)	% of different land type present in riparian zone
Wetland	*Carex sp., Lythrum sp., Scyrpus sp.*	6.3	69.3	77%
Wetland with *Salix sp.* individuals	*Typha sp., Scyrpus sp.* and *Salix sp.*	1.3	7.8	8.7%
Village		1.8	19.8	3.4%
Forest	*Robinia pseudaccacia, Quercus cerris, Q. frainetto, Q. robur, Q. petraea, Fracxinus excelsior, Populus nigra, P. alba, P. tremuloides x canadensis, Acer campestre, Ulmus laevis, Carpinus betulus, Alnus glutinosa, Tilia cordata, Salix fragilis, S. nigra*	6.9	350.9	65%
Crops		10.4	560	17.2%
Pasture		0.85	5.9	1.12%
Rivers and lakes		26.7	26.7	100%

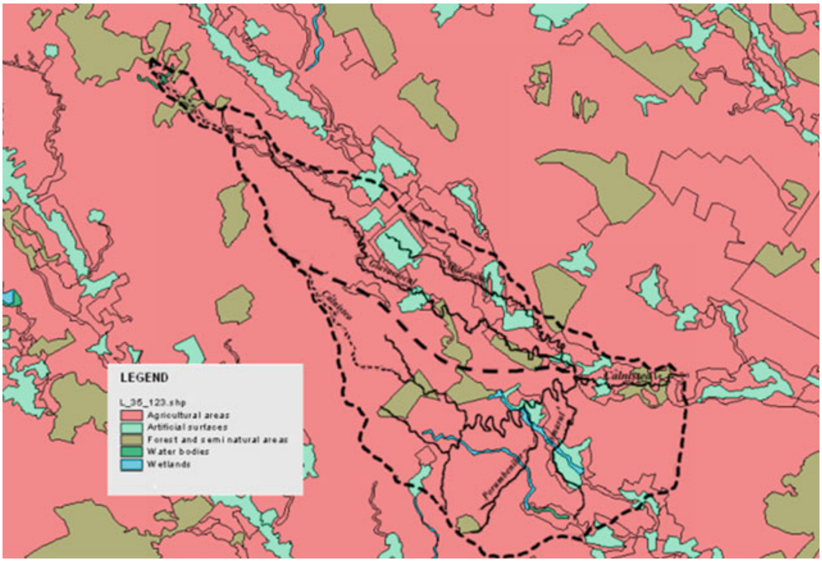

Fig. 5 Land use in river basin (Corine land cover map 2006) [19]

5 System of Agricultural Crops

Using the information from National Statistical Yearbook for 2007 generated by Agency of Payments and Interventions in Agriculture and Land Register Book, has been evaluated the crops system in Romania considering the following terms:

Agricultural area - the lands with agricultural destination, owned by natural or legal persons, classified as follows: arable land, natural pastures and hayfields, vineyards and vine nurseries, orchards and tree nurseries.

Arable land represents area which is ploughed each year or at several years, cultivated with annual or perennial plants.

Pastures represent lands covered with herbal vegetation, grown in natural way, or regenerated by sowing, for animal pasturing.

Hayfields represent lands covered with herbal vegetation, grown in natural way, or regenerated by sowing, for hay harvesting.

Vineyards and nurseries represent areas with vineyards, vine nurseries and land prepared for vineyards.

Orchards and tree nurseries represent areas with tree plantations, fruit younglings, tree nurseries and land prepared for orchards [7].

Cultivated area represents the sown area in agricultural year (October 1 - September 30) and includes:

- sown area in the previous autumn excluding re-sown area in spring with other crops;
- sown area in spring of current year.

Agricultural holding represents economic unit of agricultural production carrying out its activity under a current unique management and includes all the animals owned and all the land area used partly or completely, to perform an agricultural production, no matter of ownership type, legal type or size.

Crop agricultural production represents gross harvested production, minus losses at harvest and includes:

- production in own field;
- production of combined crops;
- production of successive crops;
- production obtained in kitchen gardens (only for vegetables, fruit, grapes) [7].

The number of types of crops at the national level is 36 of which 25(69.4%) are found in the river basins, which represents a great diversity.

The largest area is occupied by cereals for grains—wheat and corn—(62.7%), most crops are annual, and for the most of it, the sowing period, is the spring. The area occupied by industrial crops has declined lately from 24.92% to 16 0.41%, the rapeseed culture was introduced, replacing the sunflower (Fig. 6).

6 Nutrient Input

The point sources of pollution in surface water, at national level are uniformly distributed.

In Romania the diffuse and point sources of pollution are uniform distributed except the hilly and mountain areas where the agriculture activities are reduced and the human population is very low. The most vulnerable zones in pollution by nitrates are: North and North-East of Moldova, and South-Eastern Wallachia, the largest areas are in proximity of Bucharest.

In basin of most rivers are two sources of diffuse pollution: untreated sewage and fertilizers used in agriculture. Both sources of diffuse pollution create an additional intake of nutrients. At national level the population connected to sewerage is between 6.36% and 67.64% with mean value 34.9%.

In the whole area of the country, the annually agriculture input with quantities of nutrients in excess varies in different basins in range 0.39–8.7 kg/ha P; 6.91–23.6 kg/ha N; with the most large quantity in the area (Argeş-Vedea's Basin) 23.6 kg/ha N. The quantities of nitrogen and phosphorus in excess coming from agriculture lands and accumulated in the period 1998–2000 was between 60 and 87 kg/ha/year P; 12–91 kg/ha/year N, with the large quantity in Argeş-Vedea's Basin (91 kg/ha/year N).

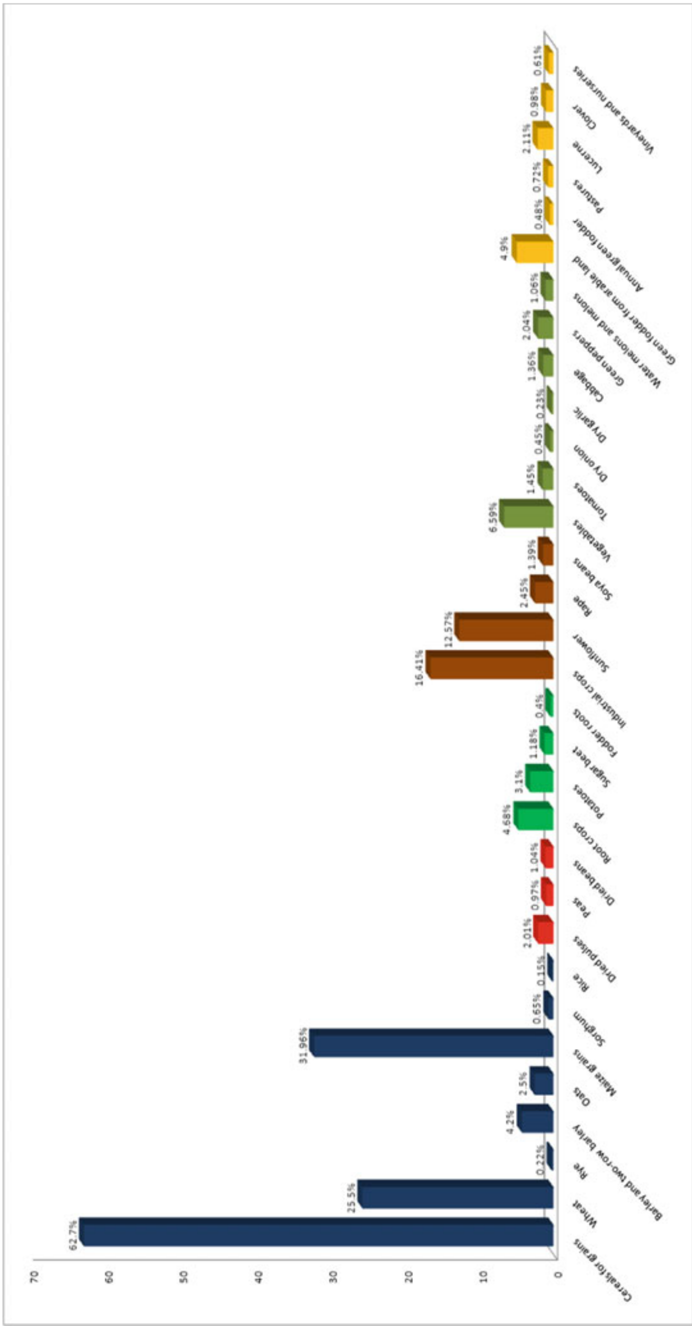

Fig. 6 Type of crops, surface (%)

6.1 Input of Nutrient by Fertilizers

In Argeş-Vedea basin not all agricultural land is fertilized the fertilizers are used only for three main crops (maize, wheat and sunflower). 3% of the cultivated area of grain maize is fertilized with mineral NPK (75 kg N/t, 130 ka P/t and 175 kg K/t) and 10% with organic fertilizer (manure). Surface of the wheat crop fertilized with NPK is about 20% and 5% with the manure is. For fertilization of sunflower crops are used only NPK and only 30% of cultivated area being fertilized. Manure comes from raising cows and has a nitrogen content of 5 kg N/t and 0.49 kg P/t (mean values in dry substance). For fertilization with NPK the farmers use between 250 and 300 kg/ha, and amount of manure used as fertilizer is between 10 and 15 t/ha. Table 4 [19, 20] https://www.ijese.org/download/volume-2-issue-5/.

6.2 Input of Nutrient by Untreated Sewage Water

In most polluted Argeş-Vedea basin, are 6 villages (Negrişoara, Glavacioc, Şelaru, Cătunu, Buteşti, Purani) and a small town (Ştefan cel Mare) situated along the river course. The population is supplied with water from the river Arges and groundwater aquifers. The N content in both sources have an average of 15 mg/L and the P content is 2.5 mg/L. After water use in the house hold, N and P contents increase at values of 25 mg/lN and 3.5 mg/lP (Table 5) [19, 20] https://www.ijese.org/download/volume-2-issue-5/.

Comparing the two sources of input of nutrient it can be noted that most is owed by the fertilization of crops. Total nutrients input introduced by fertilization of crops was 15 483 ka N and 13 206 kg P. Water used by the population and untreated made an annual intake of 8577 kg N and 1299 kg P, the contribution of population is 3169 kg N and 632 kg P. Although a small area of agricultural crops is fertilized and the amount of fertilizers used per area is relatively small these fertilizers produce a significant increase in soil nutrients. Intake of nutrients coming from

Table 4 Quantity of nutrients input in river catchment by fertilizers

Crop type	Fertilizer type	Fertilized surface (ha)	Quantity of fertilizer (t/ha)	Quantity of TN (kg/ha)	Quantity of PT (kg/ha)	Total quantity of fertilizer (t)	Total quantity of TN (kg)	Total quantity of TP (kg)
Maize	NPK	31.29	0.275	20.62	35.75	8.6	645	1119
	Manure	104.3	10	50	4.9	1043	5215	511
Wheat	NPK	166	0.300	22.5	39	49.8	3735	6474
	Manure	41.6	15	75	7.35	624	3120	306
Sunflower	NPK	123	0.300	22.5	39	36.9	2768	4797
Total		466.19	25.875	190.62	126	1762.3	**15,483**	**13,206**

Table 5 Quantity of nutrients input in river catchment by untreated sewage water

Locality	No. of inhabitants	Water volume used/ inhabitant (mean value)/ month (m^3)	Water total volume used /year (m^3)	Content of nutrients in wastewater and difference between the nutrient content of sewage and water supply (mg/L) mean values				Total input (kg/year) of nutrients, increase of nutrients added to water using			
				mg/l N		mg/l P		Kg/year N		Kg/year P	
Negrişoara	796	1.7	16,238.4	24	9	3.05	1.2	390	146	50	19
Glavacioc	814	2.1	20,512.8	26	11	3.35	1.5	533	226	69	31
Şelaru	2140	3.1	79,608	28	13	3.65	1.8	2229	1035	291	143
Cătunu	927	2.1	23,360.4	24	9	3.45	1.6	561	210	81	37
Buteşti	885	2	21,240	21	6	3.15	1.3	446	127	67	28
Purani	1685	2.8	56,616	25	10	4.15	2.3	1415	566	235	130
Ştefan cel Mare	3405	3.5	143,010	21	6	3.55	1.7	3003	858	508	243
Total	10,652	17.3	272,638.8					**8577**	**3169**	**1299**	**632**

fertilizers compared with the intake of nutrient from untreated domestic water is 5 times higher in case of N and 20 for P. Therefore the policy of protection of surface water should be focusing on the sources of diffuse pollution from agriculture and not on the wastewater. In Romania's strategy to reduce pollution of surface water that is focusing on the requirements of European Water Framework Directive the diffuse sources in agriculture are not taken into account [19, 20] https://www.ijese.org/download/volume-2-issue-5/.

7 Vegetation Description of River Basin

Taking into account physico-geographical conditions, the catchment area is located in forest-steppe biome but because of the agricultural practice the natural vegetation is replaced by agricultural lands. The remained patches of forest are dominantly composed by species of the genus *Quercus,* in particular thermophilic species like *Quercus cerris, Q. frainetto.* In in composition of this forest are present also *Fraxinus ornus Acer campestre, Ulmus laevis, Carpinus betulus, Fraxinus excelsior*, and *Tilia cordata.*

Additionally, the floodplain forests are composed by *Populus nigra, P.alba, Alnus glutinosa, Salix fragilis, S. alba.* and *S. nigra.*

The vegetation is part of subunits: U22 - Southern European forests of willow, black and white poplar (*Salix alba, Populus alba, P. Nigra);*

U14 - Panonic - Carpathian Meadow Forests *(Quercus robur, Fraxinus angustifolia)* in complex with poplar plume and willow *(Populus alba, P.nigra, Salix alba);* and U15 - Danube-Pontic forests of meadow *(Fraxinus angustifolia, F. pallisae, Quercus robur, Q. pedunculiflora)*

In subunit U14 and U15 the herbaceous layer consists of hydrophilic species such as *Rubus caesius, Glechoma hederacea, Lysimachia nummularia, Galium mollugo, mesophilous* species such as *Asparagus tenuifolius, Veronica chamaedrys, Potentilla reptans, Geum urbanum*, ruderal species such as *Amaranthus retroflexus, Arctium lappa, Bromus sterilis, Capsella bursa pastoris, Cirsium vulgare, Conyza canadensis, Daucus carota, Setaria pumila, Sonchus asper, Xanthium strumarium, Cichorium intybus, Cirsium arvense, Cirsium canum, Sonchus arvensis*, the edifying species encountered in this area are characteristic of both vegetation subunits.

The arboricol layer is represented by populations belonging to the species *Quercus robur, Q. cerris, Q. pedunculiflora, Fraxinus excelsior, F. ornus, Populus nigra, Acer campestre, A. tataricum, Ulmus laevis (Quercus robur, Fraxinus excelsior, F. ornus, Populus nigra, Acer campestre)*, with the exception of species of the genus Fraxinus, the rest are typical of U14, U15 vegetation subunits.

The shrubs layer consist in *Cornus sanguinea, C. mas, Crataegus monogyna, Evonymus europaeus, Ligustrum vulgare, Rosa canina, Rubus caesius, Salix caprea, Salix triandra, Viburnum opulus, Cornus mas, Corylus avellana, Prunus spinosa*, and contains species of shrubs characteristic of both U14 and U15 subunits.

In subunit 22 the grassy layer consists of hydrophilic species such as: *Bidens tripartitus, Polygonum hydropiper, P. mite, Galium palustre, Stachys palustris, Methha aquatica, Lycopus europaeus, Scutellaria hastifolia, Iris pseudacorus, Lythrum salicaria, Solanum dulcamara; besides these edifying species, there are also species such as: Rorippa silvestris, Gratiola officinalis, Lysimachia nummularia, Eleocharis palustris, Juncus effusus, Veronica anagallis-aquatica*, and due to the anthropic activities that occur in this area (grazing, grubbing, introduced into the vegetal and ruderal communities such as *Amaranthus retroflexus, Arctium lappa, Atriplex patula, Bromus sterilis, Capsella bursa-pastoris, Carduus nutans, Chenopodium album, Conyza canadensis, Datura stramonium, Daucus carota, Galium aparine, Lamium purpureum, Setaria pumila, Solanum nigrum, Sonchus asper, S. oleraceus, Verbascum blattaria, Xanthium strumarium, Aristolochia clematitis, Ballota nigra, Cichorium intybus, Cirsium arvense, Elymus repens, etc*.

The trees layer consists of three species: *Salix alba, Populus alba, P. nigra,* and the grassy layer is dominated by *Rubus caesius*.

Arges- Vedea basin belongs to the boundary between subunits U14, U15 and U22. Seven types of plant communities have been identified: *Molinio-Arrhenatheretea, Fraxino oxycarpe-Ulmetum, Fraxino-pallisae-angustifoliae-quercetum roboris, Populeto-Salicetum, Salicetum albae-fragilis, Phragmition, Populion albae.*

7.1 Types and Structure of Vegetation

Riparian vegetation is important for the health of waterways, contributing to the balance of oxygen, nutrients and sediment, and providing habitat and food for fauna. It grows along banks of a waterway extending to the edge of the floodplain (also known as fringing vegetation). This includes the emergent aquatic plants growing at the edge of the waterway channel and the ground cover plants, shrubs and trees within the riparian zone [19, 20] https://www.ijese.org/download/volume-2-issue-5/. Depending on the degree of representation, the most important are five riparian vegetation types: wetland (W) with *Carex sp. Lythrum sp., Scyrpus sp.*, pasture (P), mixed forest (F1), forest with Quercus species (Querceta) (F2) and agriculture land (A) (wheat, sunflower, corn crops, etc.). For each zone were estimated: structure of vegetation, dominant species, biomass, primary productivity, C, N stocks and C, N uptake.

The vegetation of wetland zone (W) is homogenous (the SD of the cover degree and height not vary more than ±5% and ±7 cm), the species richness value is low (13 taxa). In plain forested area, at catchment river level, are present 24 typologies of forest with nine types. Because the largest surface of forested area is covered with two forest types (mixed and querceta), the study of biomass and storage capacity was carried out in these two forest types. The mixed forest (F1) is a natural forest, plurien, with a great vitality, a complex structure (16 trees species) and an average productivity. The querceta forest is (F2) a young and natural forest, with a great vitality, with a structure a medium complexity (12 trees species) and a high productivity. Concerning the structure of pasture vegetation, the species richness value is highest compared with other herbaceous layer present in the other four vegetation type (32 taxa), the dominate specie is *Elymus repens*. Except for the dominant species individuals of other species are equitable distributed. The herbaceous layer has a low heterogeneity (cover degree and hight of vegetation varies slightly around the average and SD has following values of: ±5% and respectively ±5 cm) Table 6 [19, 20] https://www.ijese.org/download/volume-2-issue-5/. The most low values of species richness is in agricultural land, here, compared with the herbaceous layer present in the other four vegetation types (7 taxa), the dominate species is *Triticum aestivum*. Except cultivated plants, ruderal plants are extremely underdeveloped. The herbaceous layer is very homogeneous (cover degree in all quadrates was 100% and height of vegetation varies slightly around the average, SD of is ±5 cm). In terms of plants specific composition, the species present in common, in all type of vegetation represents less than 17%. Although mixed forest (F1) and querceta forest (F2) belong to the same vegetation unit, specific composition is completely different (less 20% taxa is in common). Vegetation on agricultural land (A) has a very low number of taxa and is similar with the pasture (P). The wetland vegetation (W) has no species in common with the other areas (A, F1, F2 and P) (Fig. 7).

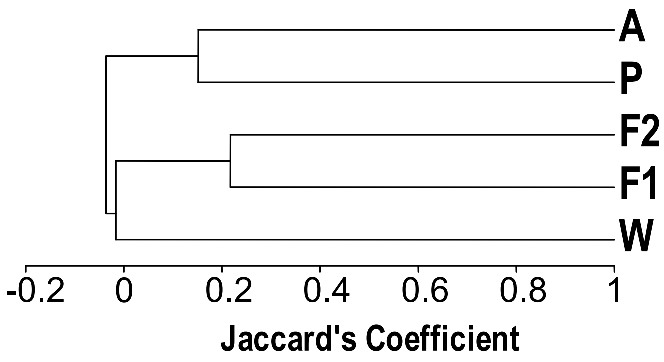

Fig. 7 Jaccard similarity between the species composition in agriculture land (A), pasture (P), querceta forest (F2), mixed forest (F1) and wetland (W) [20] https://www.ijese.org/download/volume-2-issue-5/

7.2 Biomass–Primary Production and Productivity C, N Stocks and Nutrient Uptake

The largest quantities of biomass are produce by mixed forest following by querceta forest, the layer of trees has significant contribution. The herbaceous layer present in mixed forest is least productive followed by the one from the querceta forest; because there it is increased competition for space, light and nutrients.

Nitrogen content in soil of riparian zone varies inversely proportional with altitude of land. In agriculture land where the altitude is high the content is low and in wetland where the altitude is low the content is very high. The low content of nitrogen from agricultural land, pasture and forest with low slope is due to takeover by plants, here the oxygenation and humidity conditions of the soil not favor the removed of nitrogen by denitrification. In wetland where the content of nitrogen is high the denitrification conditions are favorable because there is enough substrate for the mineralization processes. In wetland and forest with low slope the fertilization is inefficiently because there not produce an increase of content of nitrogen in soil like, in crops land, pasture and forest with high slope. In all 5 zones the nitrogen content in belowground biomass is higher compared to aboveground biomass. Except wetland, the growth trend of nitrogen content in the other zones is similar. In both type of the forest the nitrogen content in aboveground biomass, in July, is high because the plants present in herbaceous layer are at maturity, at end of biological cycle. The plants present in herbaceous layer in the forest he ends his biological cycle early to avoid competition for light and nutrients with trees leaves. Nutrient availability in soil is highly heterogeneous in space and time (Fig. 8). Soil resources are unevenly distributed in space and time. Water availability can dramatically affect soil nutrient availability, root physiology, and plant nutrient acquisition. If respiration does not decrease at a rate similar to those of water or nutrient uptake, then the roots become more costly to the plant. Moreover, dry surface soil is often associated with high soil temperature, potentially further increasing root costs [21]. Typically, if soil resources such as nitrogen or phosphorus are limiting plant growth, plants increase the amount of root biomass allocation, and thus help maintain a "functional equilibrium" between shoot acquisition of C and root acquisition of mineral nutrients [22]. In an extensive review of plant is specified the responses are non-uniform supplies of nutrients, [23]. Production of root hairs or extrametrical mycorrhizal hyphae can be a very efficient way by which a plant can increase absorptive surface for the same biomass allocation. Higher efficiency does not always lead to higher plant fitness. In a competitive environment where resources are available only for short periods, rapid resource acquisition, rather than high efficiency, may be a key to plant success [24]. High expenditures for rapid resource acquisition may be an ecologically effective strategy if fitness of neighbors is diminished to a greater extent than is the fitness of the individual exhibiting rapid growth. Plants may also overproduce tissues as a means of coping with herbivore, or as insurance against extreme events. The notion that plants might not be efficient in resource use was underscored in a review by Thomas and Sadras (2001) [25].They argue that there may be many instances where plants may support large numbers of "unproductive" tissues that may provide secondary benefits for N storage, as a buffer against herbivore, and as a way of offloading excess C and other nutrients. For example, Thomas and Sadras (2001) [21, 25] speculate that plant species in fertile environments may exhibit high rates of leaf and root turnover, not in response to a reduced need for nutrient conservation [21, 26, 27] but rather because of a greater need to offload excess resources associated with overproduction of carbohydrates. Consistent with the excess tissue hypothesis of Thomas and Sadras (2001) [21, 25] are the arguments that plants may use the alternative respiratory path as an "energy overflow" pathway [21, 28], and the evidence from the elevated CO_2 literature that shows an average of 42% enhanced soil respiration (root plus microbial respiration) in response to elevated CO_2 with-out an increase in shoot growth [29]. Our view is that while there may be times when plants appear "wasteful", especially over short time spans, maintaining redundant absorptive tissues to offset the risks of herbivory or extreme weather events still follows general concepts of optimization in an uncertain environment. Consequently, broad economic analogies [30] of plant resource acquisition and allocation may be useful tools as a first approximation for interpreting plant responses to multiple resource limitations and strategies for tissue deployment. One of the major global issues particularly at European level is the use of fertilizers in agriculture. On the one hand the need for food requires the use of a surplus of nutrients with a role in increasing agricultural production, on another part of the excess use of these nutrients leads to soil degradation and pollution of groundwater and surface water. Nitrogen uptake and accumulation in crops represent two major components of the N cycle in the agro-system. Nitrate ions that not taken up by a crop, in most of them are infiltrate in underground water. Modeling N uptake together with soil water transfers is, therefore, key in quantifying and preventing nitrate leaching [31]. 20% of the phosphorus that coming from fertilizations and

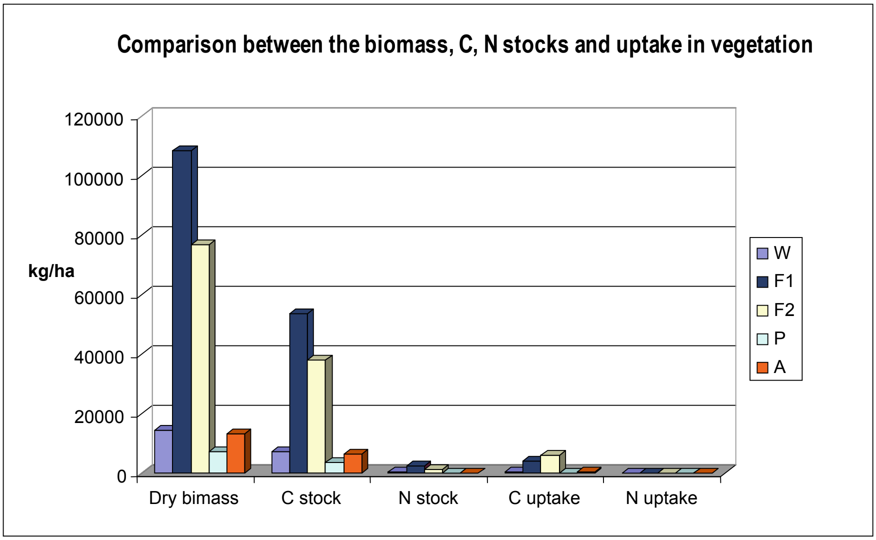

Fig. 8 The biomasses, C, N stocks and uptake in vegetation [39] https://www-pub.iaea.org/MTCD/Publications/PDF/TE_1784_web.pdf

50% of applied nitrogen to land reach receiving waters [3]. So far studies have been conducted only in the field of crop plants, but the wild plant communities that uptake part in excess of N are not been studied. Also is not been studied the role of wild plant communities, that function as buffer zones leading to reduction of nutrient pollution of ground and surface water. Plants have limited ability in retention and storing nutrients, and storage time is different, finally they reach the litter, litter that is decomposed.

7.3 *Decomposition and Nutrient Cycling*

The litter represents the dead plant parts that are in decay, which will decompose. The amount of litter is strictly related f biomass that is transformed into necro-mass. In ecosystems where no are trees and shrubs, the litter is represented by the parties dead of grass. In forests and shrubs areas the litter is represented largely by leafs. Decomposition and nutrient cycling are fundamental to ecosystem biomass production. The productivity of most natural ecosystems, are limited by nitrogen (N) input and biomass production is closely correlated with N turnover [2, 3]. Typically external input of nutrients is very low and efficient recycling of nutrients maintains productivity [4]. Decomposition of plant litter ensure for the majority of nutrients recycled through ecosystems. Rates of plant litter decomposition are highly dependent on litter quality,high concentration of phenolic compounds and

Table 6. Species composition and dominance in riparian vegetation types

Species			Frequency %	Braun-Blanquet index	Dominance
Plant species composition and dominance in wetland vegetation (W)					
Typha latifolia			2	+	
Stachys palustris			5	1	
Scirpus lacustris			100	5	First dominant
S. sylvaticus			15	2	
Lycopus europaeus			0.5	R	
Phragmites australis			2	+	
Lythrum salicaria			69	4	Second dominant
Ranunculus acris			1	+	
Galium palustre			1	+	
Epilobium hirsutum			35	3	
Juncus glomeratus			2	+	
Carex pseudocyperus			56	4	Second dominant
Acorus calamus			0.75	R	
Plant species composition and dominance in mixed forest(F1)					
Trees	Shrubs	Herbaceous			
Fraxinus excelsior	*Cornus mas*	*Bromus sterilis*	5	+	
Fraxinus ornus	*Cornus sanguinea*	*Buglossoides purpurocaerulea*	28	3	
Fraxinus pennsylvanica	*Corylus avellana*	*Galium schultesii*	34	3	
Acer campestre	*Crataegus monogyna*	*Glechoma hederacea*	67	4	Second dominant
Prunus cerasifera	*Prunus spinosa*	*Lolium perenne*	2	+	
Pyrus pyraster	*Rosa canina*	*Lysimachia nummularia*	14	2	
Acer tataricum	*Rubus caesius*	*Plantago major*	7	1	
Malus sylvestris	*Viburnum opulus*	*Plantago media*	9	1	
Quercus cerris	*Ligustrum vulgare*	*Ranunculus acris*	38	3	
Q. pedunculiflora	*Evonymus europaeus*	*Taraxacum officinale*	11	2	
Q. frainetto	*Salix triandra*	*Erigeron canadensis*	78	5	First dominant
Q. robur		*Geranium phaeum*	4	+	
Ulmus laevis		*Asperula glauca*	6	1	
Robinia pseudaccacia		*Alliaria officinalis*	23	2	
P. tremuloides x P. canadensis		*Stellaria aquatic*	4	+	
Populus nigra		*Mercurialis perennis*	0.75	r	
Plant species composition and dominance in Querceta forest (F2)					
Trees	Shrubs	Herbaceous			
Fraxinus excelsior	*Cornus mas*	*Anemone nemorosa*	17	2	
Fraxinus ornus	*Cornus sanguinea*	*Buglossoides purpurocaerulea*	6	1	
Fraxinus pennsylvanica	*Corylus avellana*	*Asparagus tenuifolius*	3	+	
Acer campestre	*Crataegus monogyna*	*Corydalis cava*	21	2	
Populus alba	*Rosa canina*	*Corydalis solida*	24	2	
Prunus cerasifera	*Rubus caesius*	*Circaea lutetiana*	0.5	R	
Pyrus pyraster	*Viburnum opulus*	*Galium mollugo*	11	2	
Quercus cerris	*Ligustrum vulgare*	*Galium schultesii*	9	1	
Q. pedunculiflora		*Geranium phaeum*	7	1	
Q. frainetto		*Geranium pretense*	4	+	
Q. robur		*Geum urbanum*	29	3	Second dominant
Tilia cordata		*Glechoma hederacea*	58	4	First co-dominant
		Heracleum sphondylium	1	+	
		Lamium album	2	+	
		Lysimachia nummularia	14	2	
		Plantago major	9	1	
		Polygonatum latifolium	3	+	
		Potentilla reptans	2	+	
		Ranunculus acris	28	3	
		Ficaria verna	65	4	First co-dominant
		Rumex crispus	0.7	R	
		Salvia nemorosa	2	+	
		Scilla bifolia	18	2	
		Silene vulgaris	12	2	

		Veronica chamaedrys	8	1	
		Viola odorata	46	3	Second dominant
Plant species composition and dominance in pasture (P)					
Amaranthus retroflexus			4	+	
Arctium lappa			2	+	
Bromus sterilis			3	+	
Capsella bursa-pastoris			3	+	
Daucus carota			1	+	
Echinochloa crus-galli			3	+	
Erigeron canadensis			11	2	
Erodium cicutarium			0.5	R	
Setaria pumila			0.7	R	
Achillea millefolium			1	+	
Cichorium intybus			2	+	
Galega officinalis			0.5	R	
Hypericum perforatum			1	+	
Lolium perenne			23	2	
Lotus corniculatus			9	1	
Mentha longifolia			3	+	
Plantago major			4	+	
Potentilla reptans			1	+	
Prunella vulgaris			16	2	
Ranunculus acris			2	+	
Senecio jacobaea			3	+	
Taraxacum officinale			5	+	
Trifolium hybridum			7	1	
Trifolium pratense			8	1	
Trifolium repens			11	2	
Dactilis glomerata			4	+	
Elymus repens			76	5	Dominant
Vicia cracca			11	1	
Cirsium vulgare			0.4	R	
Inula britanica			1	+	
Ranunculus sardous			1	+	
Sonchus asper			0.7	R	
Plant species composition and dominance in agriculture land					
Triticum aestivum or *(Helianthus annuus)*			100	5	Dominant
Cirsium vulgare			1	+	
Setaria pumila			0.5	R	
Sonchus asper			1	+	
Bromus sterilis			2	+	
Viola tricolor			0.5	R	
Vicia cracca			6	1	

especially the lignin, in plant litter has a retarding effect on litter decomposition [32, 33]. Globally, rates of decomposition are mediated by litter quality and climate [37]. Ecosystems dominated by plants with low-lignin concentration often have rapid rates of decomposition and fast nutrient cycles [38].

The decomposition of the litter is a process that follow an exponential law and whose rate can be appreciated by calculating the constant K.

Values of decomposition rate constant (k) are comparables with values present in literature. The highest value of the constant decomposition rate (k) was recorded in forest with low slope—F1—mixed forest; here the decomposition process is most intense. In forest with high slope—F2—querceta forest the k value is close to that of F1. High speed of decomposition in F1 is due a saturated soil in water (here is sufficient water like humidity necessary for bacterial exo-enzymes activity) and the nature of litter (the quantity of lignin and cellulose in trees and shrubs leafs is low to compare the wheat stems and *Scyrpus* sp. *Typha* sp.) (Table 7).

Table 7 Comparison between average values of k with average values present in literature

Zone	K ($days^{-1}$) mean values	K ($days^{-1}$) mean values present in literature
W	2.281×10^{-2}	2.464×10^{-2} Gessner et al. [34]
F1	5.327×10^{-2}	2.354×10^{-2} Nelson et al. [35]
P	4.283×10^{-2}	1.044×10^{-2} Nelson et al. [35]
A	2.578×10^{-2}	0.332×10^{-3} Salamanca et al. [36]
F2	5.061×10^{-2}	0.367×10^{-3} Aerts [27]

The lower value of k was calculated in wetland; plant species present here are adapted to high soil moisture conditions; in tissues structure of these plant the cell wall are impregnated with silica salts that is difficult to break down in small fragments. The wheat straws have also in the structure the tissues impregnated with silica salts; therefore the value of k in agriculture land is low and similarly with wetland. In both agricultural land and in wetland the decomposition process takes place slowly. More complex compounds of C are decomposed more slowly and may take many years to completely breakdown.

8 Conclusions

Riparian zones are the transitional areas between land and water, including the margins of streams, rivers, lakes, and wetlands. They are rich in biodiversity and play an important role in protecting water quality and stream ecosystem health. Riparian vegetation functions as a large sponge that reduces surface flow and absorbs the nutrients (C, N, P) in excess and pollutants from storm water runoff During the development process, riparian areas are degraded when vegetation is removed, the terrain is cultivated or plowed, are installed the utilities, are built the different structures and river borders are regularized. These changes to the landscape and subsequent human activity in the riparian zone have consequences on ecosystem health from impact of nutrients in excess that came from fertilizers, wastes, atmospheric pollutants generated by cars the roads, and soils degradation [40]. The temperate forests play a very important role in terms of the amount of C and N stored, storage period of them and fertility of the soil.

In trees layer the amount of nutrients (C, N) stored in the wood, is 10 times greater than that stored in the leaves. The nutrients stock that accumulate in wood as productivity, grow from year to year and only the leaves supplies the litter, which decomposes. In the two forest types (F1 and F2), 4/5 the amount of litter is decomposed, and 1/5 accumulates at the soil surface and supplies the horizon 0 of the soil with organic matter. This organic matter plays a fundamental role in soil processes; this is an energy source of microorganisms and precursor in soil humic acids [19, 20, 39] https://www-pub.iaea.org/MTCD/Publications/PDF/TE_1784_web.pdf. Although part of N is lost in the process of denitrification,one of the final stage of process of decomposition; a large amount of N returns to soil as nutrients from which is taken by plants. Making a unilateral analysis regarding takeover efficiency and nutrient use by plants in crops, imply the risk of ignore the role of other types of ecosystem in nutrients cycle.

A holistic approach, those make a simultaneous analysis for all function of ecosystems (reducing pollution, creating local microclimates, etc.) outside the production of them can give an overview and help making the best decisions concerning the use of different types of land. Natural and semi-natural ecosystems are the main sources in the production of resources and energy generation and play an important role in reducing of pollution. In modern society the required of resources and energy to developed is greater, also the human pressures exerted on ecosystems and biodiversity is in increase, which implies the need for preservation of these. Keeping an ecosystem mosaic structure is an ideal solution to harmonize the development of society with nature conservation. A green infrastructure with lakes and rivers, wetland, different types of forest, pastures, shrubs including different types of crops, it represent the ideal structure to meet both goals [19, 20, 39].

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