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Assessment of pollution in the Black Sea, monitoring methods of riparian areas and best management practices

<u>Edited by</u>

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Assessment of pollution in Greece and the Black Sea, monitoring methods of riparian areas and best management practices

George N. Zaimes and Valasia Iakovoglou

1.1 Introduction

The Black sea is a closed sea surrounded by many different countries. Some of these countries belong to the EU, other were former states of the USSR, in addition to countries that belong to Asia. Most countries have different regulations in regard to water pollution measures making the management of Black Sea quite difficult. The Black Sea area is the end point for water sources such as rivers and streams. Consequently, the significance of the imput of riparian areas in helping retain clean waters at those closed seas is substantial.

Specifically, riparian areas are interconnected with their watershed (Bruno et al., 2014; Larsen et al., 2015) but also can be heavily influenced by local factors (Zaimes et al., 2019a). Sediments are a major nonpoint source pollutant worldwide that has severe repercussion to the environment especially aquatic ecosystems. Sedimentation, that is the direct result of the loss (erosion) of sediments from other aquatic areas or land-based areas, can be detrimental or beneficial to aquatic environments. Moreover, sediment impoverishment (erosion or lack of replenishment) in an area can be as bad as too much sedimentation. Human activities have significantly enhanced sedimentation as well as sediment loss and can be land-based (i.e., agriculture, forestry, construction, urbanization, recreation) and water-based (i.e., dams, navigation, port activities, drag fishing, channelization, water diversions, wetlands loss, other large-scale hydrological modifications).

Humans are also affecting the presence of the marine litter is defined as any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment. It consists of items that have been made or used by people and deliberately discarded into the sea, rivers that were brought indirectly to the sea with rivers, sewage, storm water or winds. Marine debris, another term used for marine litter, is human-created waste that has been either deliberately or accidentally released in a river, lake, sea, ocean or waterway. Floating oceanic debris tends to accumulate at the center of gyres and on coastlines, frequently washing aground, when it is known as beach litter. Deliberate disposal of wastes at sea is called ocean dumping. Naturally occurring debris, such as driftwood, are also present.

Consequently, the importance of riparian areas in achieving sustainable water management and also reduce pollutants is substantial. Working on the best possible management tools in order to achieve sustainable ecosystems that result to clean waters is of high importance So the implementation of Integrated Water Resources

Management plan is essential for their long-term sustainable welfare through the use of monitoring tools both at the small (e.g., reach) and the large (e.g., watershed) scale. Further, the use of Nature-based Solutions (NbS) is one of the most recently methods used to improve the management and conservation of the ecosystems of the region along with the welfare of the people through the use of ecosystems services. That also helps sustain societal challenges such as climate change, food security or natural disasters.

1.2 Riparian Areas - Importance – Assessment

1.2.1 Importance of Riparian Areas

The sustainable management of riparian areas has been brought to the forefront in the last 4-5 decades by researchers, land and water managers, as well as policy makers because of the many and important ecosystem services they offer for the welfare and development of society [Buchanan et al., 2020; Molina-Holgado et al., 2020]. The services of these areas have been known for thousands of years to humans who have used them, which has led to their extensive degradation. The conservation and protection of riparian areas is a main priority in most developed countries and can help meet the UN sustainable development goals of clean water and sanitation (#6), climate action (#13), life below water (#14), and life on land (#15).

Riparian areas are the transition zones between aquatic and terrestrial ecosystems [Naiman et al., 2005; National Research Council, 2002]. This leads to a gradient of characteristics as you move from the terrestrial to the aquatic ecosystem [Stella et al. 2013]. Specifically, the zones of the riparian area that are closer to the terrestrial ecosystem retain characteristics of the terrestrial ecosystem, while as you get closer to the aquatic ecosystem many characteristics change and are more similar to those of the aquatic ecosystem. Thus, the term “transition zone” can have two meanings; first, the zone between an aquatic and terrestrial ecosystem, and second in regard to the different characteristics of the riparian areas that transition as one moves from the aquatic to the terrestrial ecosystem. In addition, riparian areas are azonal since they can be found in al-most all terrestrial longitudes, latitudes, and altitudes [Baker et al. 2003]. The high diversity of riparian areas worldwide along with the diversity within each riparian area makes it difficult to establish a concrete and agreeable definition for this unique ecosystem.

The most distinguishable feature of the riparian areas is the vegetation [Zaimes et al., 2010] that differs in density as well the species composition from the adjacent terrestrial areas [Manning et al., 2020]. The vegetation is typically hydrophilic and is the result of the environmental conditions of the riparian areas. Specifically, the greater water availability year-round in the soil; since the water table is relatively high and the root systems have continuous access to water. In addition, these areas experience frequent floods, thus, the hydrophilic vegetation that can withstand waterlogged soil conditions have an advantage in establishing and occupying these areas [Stromberg and Boudell, 2013]. Flooding can also open new areas for recolonization of pioneering species and the riparian stands can have a diversity of ages [Kramer et al., 2008]. The flooding and the consequent erosion and deposition that occurs lead to unique fluvio-geomorphologic conditions that the riparian vegetation is adapted too. By not allowing the flooding of riparian areas, other species will gain the advantage that could lead to substantial changes in the riparian area communities. These disturbances also lead to soils that are considered young and very rich in nutrients [De Sosa et al., 2018]. The soil profile is not the typical one and can have buried horizons, while along the reach the soils can differ depending if they are a deposition or erosion area. Finally, droughts are another disturbance that riparian areas frequently face that can actually help in the expansion of the vegetation in the stream channels or under extreme intense events can lead to the death of the riparian vegetation.

Agriculture is considered the main culprit for the extreme degradation of riparian ecosystems [Tufekcioglu et al., 2020; Zaimes et al., 2019]. The nutrient rich soils along with their close proximity to water make riparian areas prime lands for agricultural production. The vegetation of the riparian are-as was in many cases completely eradicated and replaced with crops or in other cases a narrow strip of natural vegetation was left. These activities eliminate or substantially decrease the other ecosystems services they offer such as water quality, wildlife habitat, flood protection, ground water recharge etc. In addition, another major threat is urbanization [Cao and Natuhra, 2020; Iakovoglou et al., 2013; Johnson et al., 2020]. More and more people are congregating in cities and towns that are typically located along rivers and deltas. Riparian areas in many cities are devoid of vegetation that cause their fragmentation. The re-establishment of riparian areas can, in both agricultural and urban settings, provide major benefits and enhance the ecosystem services they can offer [Cole et al., 2020]. This is the reason why efforts to restore and conserve riparian areas are made worldwide [Zaimes, 2020].

Riparian areas are semi-aquatic ecosystems with unique hydrologic and soil characteristics. Climate change is increasing the mean and extreme temperatures and altering precipitation patterns. These changes are also impacting the hydrologic cycle and will most likely, first impact semi-aquatic ecosystems [Albano et al., 2020; Zaimes et al., 2011]. The hydrologic cycle is becoming faster with more extreme events. In regard to riparian areas, despite being disturbance driven ecosystems, the increase in flood events and magnitudes along with increase of the intensity and duration of drought events could lead to new hydrologic conditions that exceed their natural hydrologic regime thresholds. Exceeding the ecosystem’s natural thresholds could substantially alter them. In addition, the decrease of freshwater availability will increase anthropogenic needs and put more pressure on aquatic and semi-aquatic ecosystems.

The Mediterranean region is unique because of its climatic and topographic conditions, frequent wildfires and extensive over thousands of years human use [Olson et al., 2001]. These characteristics also lead to unique riparian areas in regard to their vegetative characteristics and flow conditions of the adjacent water bodies [Zaimes, 2020]. The vegetation of Mediterranean riparian areas can have woody to herbaceous vegetation or mixtures with interannual fluctuations in richness and composition more diverse that those of temperate ones [Feio et al., 2014; Ferreira et al., 2019]. These assemblages are also characterized by shorter life spans, desiccation resistance or drought avoidance mechanisms, and high colonization rates [Bonada and Resh, 2013; Santos, 2010]. The vegetative characteristics are also a consequence of the adjacent water bodies stream flows. Mediterranean rivers and streams have natural high flow variability. Wet winters can lead to floods while severe droughts in the summer can cause no flow conditions [Cid et al., 2017]. The streams in high altitudes have perennial flow with the highest flows occurring after rain and snowmelt in spring [Lobera et al., 2015]. In contrast, streams located in lowland areas, have intermit-tent or ephemeral flow [Lobera et al., 2015] and are called “torrents” in Southern Europe [Emmanouloudis, 2011]. Torrents, compared to rivers, have a much more irregular flow that can change in hours from no flow to a flash flood event. Finally, sustainable environmental management is required in the Mediterranean since many consider it as one of the most sensitive regions to climate change [Rault et al., 2019].

The European Union based on Water Framework Directive (WFD; 2000/60/EC), re-quires Greece and all member countries to assess the features of their riparian areas [Van den Broeck et al., 2015; Magdaleno and Martinez 2014]. In addition, EU programs such as the Natura 2000 Network and International programs such as the Ramsar Convention have recognized the importance of riparian areas in the Mediterranean region and particularly in Greece by designating many riparian areas as protected [Zaimes et al., 2010; Ferreira et al., 2019]. This has led to many research efforts on the conservation and sustainable management of these ecosystems, particularly in the European Mediterranean areas. Still Greece, although lately there have been efforts, is still lagging research wise compared to other EU Mediterranean countries [Zaimes et al., 2011].

The many important services that riparian areas offer along with the fact that they have been heavily degraded, showcase the need to assess their current condition in order to be able to develop sustainable management plans that take into consideration climate change. This is particularly true for Greece that only in recent decades researcher have made some efforts to sustainably manage these ecosystems [Zaimes et al., 2011; Schismenos et al., 2019]. The objective of this study was to present several different studies on riparian areas that will help assess their current condition of different representative environments throughout Greece. In addition, several different methods that were used to assess riparian areas will be presented and evaluated in regard to their effectiveness and applicability. The derived conclusions could be applicable throughout the European Mediterranean region since the studied reaches are representative of riparian areas, particularly adjacent to streams and torrents. Overall, the implementation of these methods could help improve the monitoring and sustainable management of riparian area in the European Mediterranean region.

1.2.2 Assessment and Monitoring of Riparian Areas

To assess riparian areas several different methods have been developed worldwide. The one used and preferred, depends on the objective and the spatial and temporal scale of the study and the availability of funds. In this paper, methods better suited for both small-scale (e.g., stream reach) and large-scale (e.g., watershed) study areas are presented.

Two different methods are recommended for the small-scale studies that focused on the reach of a torrent, stream or river. Specifically, the first type is visual protocols and the second bioindicators (e.g., insects and birds). Visual protocols are very popular because they can fast and accurately (if done correctly) provide a first assessment on the riparian study area. Of course, they provide a preliminary assessment and based on its results more de-tailed monitoring might need to take place afterwards.

The two visual protocol recommended are the Stream Visual Assessment Protocol (SVAP) [Bjorkland et al., 2001] and the Ecological Status of Riparian Vegetation index (QBR) [Munné et al., 2003]. Both have been used extensively in many studies in the Mediterranean and around the world and are accepted as useful tool for the quick assessment of riparian areas. The SVAP focuses on stream characteristics and provides the ecological condition primarily of the streams but also the riparian areas. It has been developed by the United States Department of Agriculture, Natural Resources Conservation Service and has been adopted and applied worldwide. Since Mediterranean riparian areas have unique characteristics [Zaimes et al., 2010], the SVAP was modified to better assess Greek riparian areas [Iakovoglou et al., 2013]. Specifically, at each sampling location 14 parameters are visually assessed with values ranging from 0 to 10 (0 the worst and 10 the best). These 14 parameters are averaged, and the stream reach is classified as Poor (≤6.0), Moderate (6.1 to 7.5), Good (7.6 to 9.0) and Excellent (>9.0). The QBR focuses on the riparian areas with an emphasis on the riparian forest quality. The assessment is based on three parameters of the riparian area (i-total vegetation area and cohesion, ii-tree overstory cover and shrubs and iii-understory vegetation and vegetation cover quality) and one on the stream channel and bed (human changes). Each parameter can get a maximum value of 25 point and afterwards these are added and classified as Bad (≤25), Not Satisfactory (30–50), Satisfactory (55–70), Good (75–90), Natural State (≥95). Since this method was developed in Spain it is more readily adopted for other Mediterranean regions such as Greece.

In regard to the applicability of the two visual protocols used, SVAP and QBR, we highly recommend their adoption by the responsible authorities in Greece for three reasons. Based on our personal experience with several different protocols for riparian areas and streams it appears that these two are easily applicable by managers with basic knowledge in riparian areas. Another advantage is repeatability, especially for SVAP. When tested by different users in most cases the results were very similar. Finally, another major advantage is that once trained, surveying a site can be conducted quite quickly. We also recommend that both SVAP and QBR should be used together. The categorization based on each protocol was different in some reaches. This has to do with the fact that the SVAP focus more on the stream characteristics while the QBR focuses more on the riparian vegetation characteristics. The two protocols are complimentary to each other, by focusing on different aspects in regard to the ecological integrity of streams and riparian areas. Of course, in case there are time, labor or money constraints in regard to monitoring the riparian areas, land or water managers should choose which protocol to use based on the objective of the study. If an assessment on the stream is the focal point, we recommend the SVAP; if the riparian vegetation is the focal point, we recommend the QBR. Overall, their adoption and implementation by the responsible authorities in Greece should help develop an extensive database enhancing the limited spatial scale of the currently surveyed reaches thus providing a more rigorous picture on the current condition of the riparian areas in Greece.

Another assessment tool that is gaining more acceptance is bioindicators for riparian and river ecosystems. They are preferred because they are less variable than physicochemical indicators [Sharifinia et al., 2016] but still can showcase water and habitat quality changes [Sharma et al., 2008]. Certain endemic insects and bird populations have been used since some can be very sensitive in regard to their richness, composition and diversity, based on the stream and riparian habitat conditions, especially in relation to anthropogenic changes [Berges et al., 2010; Hassall, 2015; Viegas et al., 2014]. We recommend as potential bioindicators ground-dwelling insects [Zaimes et al., 2019], small birds [Kontsiotis, 2019] and flying insects, specifically dragonflies (Odonata) [Zaimes et al., 2017]. The comparisons among the reaches were made with the use of Diversity Indices; specifically: (a)

Shannon-Wiener Diversity Index (H), (b) Shannon-Wiener Equitability Index (EH) and (c) Simpson's Index (D) [Shannon and Weaver, 1949; Simpson, 1949].

All three suggested bioindicators, have the potential to be scientifically sound tools for monitoring riparian areas and streams. Different studies have also shown that small birds [Kontsiotis et al., 2019; Batisteli at al., 2018], ground-dwelling insects [Viegas et al., 2014; Zaimes et al., 2019; Perry and Herms, 2019] and dragonflies [Zaimes et al., 2017; Lee et al., 2018] are effective monitoring tools. Although the use of bioindicators shows promise, one of the main disadvantages is the need for more intensive training compared to the protocols, in order to be able to identify the birds, dragonflies, or ground-dwelling insects. This is essential for the small birds and dragonflies since the surveys are conducted by identification in the field. In contrast for the ground-dwelling insects since litter traps were used, the insects could be collected and then sent to the ap-propriate laboratory for identification. This difficulty is also why in many cases it is suggested that eventually instead of measuring all the insects or small birds, certain species (ideally one) should be selected to be measured. In the ground-dwelling insects, *Silpha obscura* was selected in one study [Zaimes et al., 2019] while for the birds, species that are endangered or have characteristic ecological requirements could be selected. This would significantly reduce the training time. Finally, the main difference between the visual protocols and the bioindicators is that the first method provides a quick initial assessment of riparian area conditions while the second can provide a more accurate assessment of the quality of the ecosystem although they are more labor-intensive and time-consuming. Typically, visual protocols should be initially used and based on their results, certain bioindicators could be selected and used for more targeted and detailed studies.

Field methods are essential to assess the actual conditions of the stream reaches of riparian areas and the authors believe they should be a mandatory component of any management and monitoring plan. Nonetheless, they are labor-intensive and time consuming and the new technologies that have been developed should be used more when conducting environmental studies. Methods based on these new technologies can be complimentary to the field methods, previously described. The methods used were based on Geographic Information Systems (GIS), remote sensing and modeling. A major advantage of these methods is that they can be applied at larger scales and even for the entire watershed. With the GIS method, the "buffer" function was used to estimate the area of the different land-uses/vegetation covers, up to a specific distance for the stream edge on both sides of the stream [Zaimes et al., 2011; Giatas et al., 2016; Kasapidis et al., 2017; Savopoulou et al., 2017]. Initially, relevant maps, aerial photos, satellite images or google map images are inserted into GIS. Afterwards the stream network and the different land-uses/covers are digitized.

Land-use/vegetation cover of the riparian area plays the most important role in regard to their ecological integrity [Zaimes et al., 2019; Clerici et al., 2014]. GIS allow for a quick assessment of the land-use/vegetation cover of large lengths of riparian areas, even at the entire watershed scale. This quick assessment can provide a first perspective on the conditions that can be expected in the riparian area and its stream. The accuracy of the assessment will depend on the resolution of the images of the data layers that are used. A main advantage of this method is that most natural resource management services use GIS. The buffer function, as long as the land-use/vegetation cover layers are available, is a simplistic process easily implemented by those with basic knowledge of GIS. This method should be the first step in the assessment of riparian areas. Such a database could be easily developed if the responsible authorities would adopt this method and we strongly believe that it would be complimentary to the database that could be developed based on the SVAP and QBR protocols. This can also help locate the riparian areas that would require additional field measurements leading to a more targeted approach. Targeted approaches for riparian areas should be preferred because they are a cost-effective management practice [Zaimes et al., 2019; Magdaleno and Martinez, 2014]. Once specific riparian areas are targeted, then, in these areas field measurements (visual protocols and/or bioindicators) can be applied.

Riparian areas offer many ecosystem services to different stakeholders, so in heavily populated areas their sustainable management requires detailed, long-term and scientific information on their ecological integrity and functionality. To maximize the benefits restoring riparian areas, a broader perspective on their ecosystem services needs to be included when management plans are developed [Riis et al., 2020]. Using new technologies can help develop management plans that are based on science-based information and incorporate many ecosystems services. Two scientific fields that could really help the sustainable management of riparian areas are remote sensing and modeling [Duke et al., 2007].

The remote sensing methods are the vegetation indices. Vegetation indices can showcase changes in vegetation through time [Higginbottom and Symeonakis, 2014] and have also been used for assessing riparian areas [Wilson et al., 2016]. Some vegetation indices that can be used are: (a) 2 band Enhanced Vegetation Index (EVI 2) [Jiang et al., 2007], (b) Green Atmospherically Resistant Vegetation Index (GARI) [Gitelson et al., 1996], (c) Land Surface Water Index (LSWI) [Chandrasekar et al., 2010], (d) Normalized Difference Burning Ratio (NDBR) [Key et al., 2002], (e) Normalized Difference Vegetation Index (NDVI) [Tucker, 1979], (f) Normalized

Difference Water Index (NDWI) [Gao, 1996], (g) Perpendicular Vegetation Index (PVI) [Richardson and Wiegand, 1987], (h) Vegetation Condition Index (VCI) [Liu and Kogan, 1996]. To implement these indices satellite images could be used that span for several years or decades. Such images are freely available through Landsat but can be purchased from Worldview.

Finally, prediction models can be used to examine the relationship between changes in vegetation and other climatic and terrestrial variables. Specifically, the Random Forests model [Breiman, 2001] is recommended. The model has been used in the past with good results on studies in regard to riparian and coastal areas [Zaimes et al., 2019; Cortes et al., 2013; Nguyen et al., 2019]. The reason for its selection is because it can analyze inputs with a different nature and scaling, it randomly selects training samples and predictors' values leading to an independent, evenly distributed regression tree and provides meaningful metrics [Gounaridis et al., 2018; Gounaridis et al., 2019]. The variables used as the predictors for the riparian vegetation of the Random Forest can be territorial and climatic (total 26 variables). The territorial variables can be (a) Elevation, (b) Slope, (c) Distance from croplands, (d) Distance from sea, (e) Distance from river, (f) Distance from dam, and (g) Distance from residential areas. The climatic variables were: (a) Annual Mean Temperature, (b) Mean Diurnal Range, (c) Temperature Seasonality, (d) Max Temperature of Warmest Month, (e) Min Temperature of Coldest Month, (f) Annual Precipitation Annual Precipitation, (g) Precipitation of Wettest Month Precipitation of Wettest Month, (h) Precipitation of Driest Month. Metrics that can be used to quantify the importance and contribution of each parameter in vegetation change are the Mean Decrease Accuracy and Mean Decrease Gini [Gounaridis et al., 2018; Gounaridis et al., 2019].

Both methods need more specialized personnel compared to the other three methodologies described previously (protocols, bioindicators and GIS). These should be applied in riparian areas that based on the preliminary assessment tools, showcased strong indications of serious environmental problems. Their results would allow the implementation of management plans and actions that address specific problems identified by the vegetation indices or models. Following is a diagram (Figure 2.1) on the potential use of the above-described methods. The methods use will depend on the objective of the study and the financial report.

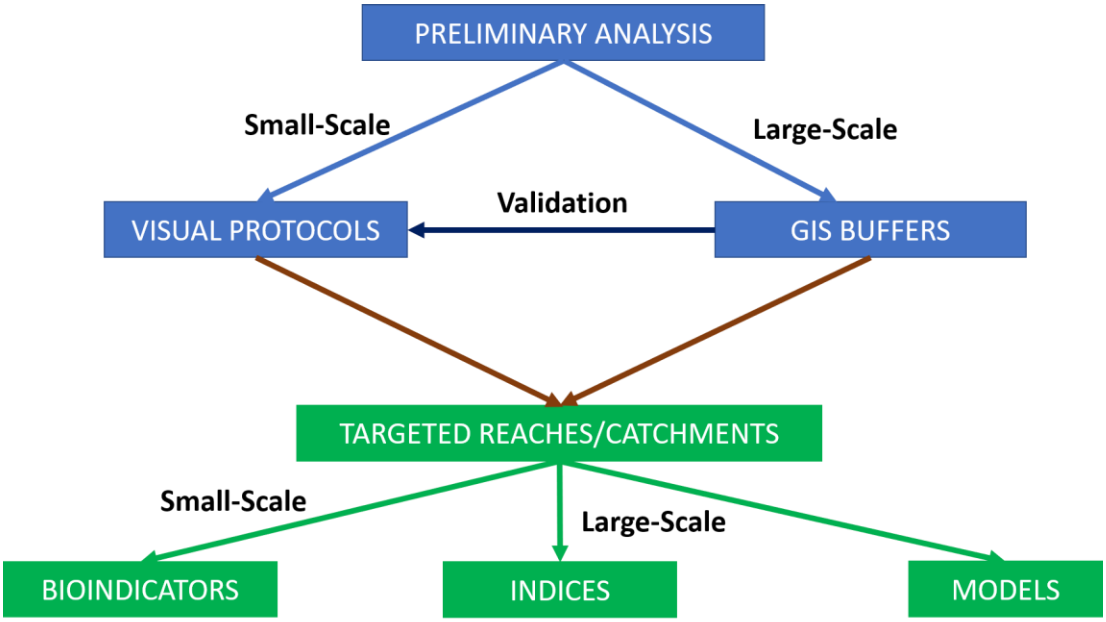

Figure 2.1. The different methods that can be used to assess riparian areas based on analysis and the scale requirements of the study.

1.3 Nature-Based Solutions

1.3.1 Best Management Practices for Riparian Areas

Riparian areas are interconnected with their watershed (Bruno et al., 2014; Larsen et al., 2015) but also can be heavily influenced by local factors (Zaimes et al., 2019a). To sustainably manage them, Integrated Water Resources Management needs to be applied (Emmanouloudis et al., 2011). This recommends management plans at the watershed scale and the use of large-scale monitoring methods. At the same time, when specific areas of the watershed that are heavily degraded are identified, small-scale monitoring should be used (e.g., protocols and bioindicators). The many ecosystem services they offer to human welfare should make it a priority in regard to conservation, but at the same time make it difficult due the many stakeholders that have an interest on them. This is why new innovative practices based on ecosystem-based approaches or nature-based solutions need to be implemented (Schismenos et al., 2019; Zaimes et al., 2019a; Lilli et al., 2020; Symmank et al., 2020). Ecosystem-based approaches include several different management actions that are based on the principles and process of natural ecosystems with the long-term objective to reduce the vulnerability while also increasing the resilience of communities (Doswald et al., 2014). Nature-based solution are based on natural environmental features and processes that can be implemented in cities, landscapes and seascapes (Cohen-Shacham et al., 2019). The goal is to provide social, environmental and economic benefits and resilience to society. Overall, nature-based solutions need to be cost-effective, enhance the ecosystem services and promote biodiversity. Both practices have not been extensively implemented in Greece although they have shown great potential in the conservation and enhancement of natural ecosystems such as riparian areas. Need to note that text of the following sub-chapters in based on the Publication "Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds.) (2016). Nature-based Solutions to address global societal challenges. Gland, Switzerland: IUCN. xiii + 97pp."

1.3.2 Introduction to Nature-based Solutions

Nature-based Solutions (NbS) use ecosystems and the services they provide to address societal challenges such as climate change, food security or natural disasters (Cohen-Shacham et al., 2016). IUCN defines NbS as: "Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."

Nature-based Solutions can often be used in conjunction with others types of interventions. Food security challenges, for example, are best addressed using a combination of measures including NbS (e.g., introducing agroforestry systems, restoring wetlands) as well as more conventional solutions such as improving access to food and making trade policy more supportive of local food supply.

Recognition of the fundamental role that ecosystems play in supporting human wellbeing is a cornerstone of many indigenous people's belief systems and has been reflected in traditional knowledge systems for centuries. However, it was only in the 1970s that the idea of environmental or ecosystem services began to establish itself in the modern scientific literature. By the 1990s it was generally realized that a more systematic approach was required to document and understand this relationship between people and nature. The 2005 Millennium Ecosystem Assessment, itself a product of this growing awareness, provided a strong evidence base for subsequent policies to promote the conservation, restoration and sustainable management of ecosystems while also taking into account the increasing demands placed on ecosystem services (Millennium Ecosystem Assessment, 2005). A few years later, during the late 2000s, the term 'Nature- Based Solutions' emerged, marking a subtle yet important shift in perspective: not only were people the passive beneficiaries of nature's benefits, but they could also proactively protect, manage or restore natural ecosystems as a purposeful and significant contribution to addressing major societal challenges.

The emergence of the NbS concept in environmental sciences and nature conservation contexts came as international organizations, such as IUCN and the World Bank, searched for solutions to work with ecosystems rather than relying on conventional engineering interventions (such as seawalls), to adapt to and mitigate climate change effects, while improving sustainable livelihoods and protecting natural ecosystems and biodiversity (Mittermeier et al., 2008). Following the same approach, 'Natural solutions' has been used as a similar concept, in this case focusing on the particular role of protected areas in offering solutions to societal challenges such as climate change and desertification (Dudley et al., 2010). More broadly, the development of the NbS concept has been firmly grounded in global practice as the nature conservation and development sectors, formerly viewed as having contradictory objectives, have moved toward a common recognition of the positive as well as negative linkages between people and nature. This has been evidenced by, for example, the emergence and evolution of the whole field of sustainable development. Similarly, perspectives on nature conservation have broadened considerably over the last half-decade, expanding beyond an exclusive focus on the protection of wilderness and wild, charismatic species to approaches that tackle the drivers of biodiversity decline such as pollution and the loss of species habitats. More recently, the conservation agenda has evolved further to embrace a more complex understanding of social-ecological systems, as evidenced by the establishment of the Ecosystem Approach, which was endorsed and adopted by the CBD in 1995 (Mace, 2014; CBD, 2004).2 The international ambitions of both the sustainable development and biodiversity conservation communities now clearly take into account the need to provide sustainable benefits for people and the broader environment.

1.3.3 Definition of Nature-based Solutions

Good science requires the use of precise definitions rather than phrases working as metaphors (Aronson, 2011). Furthermore, as multiple definitions of NbS develop, they may lead to some confusion about the concept and potentially hinder its development and uptake. In order for NbS to become operational, a clear definition and a set of principles are needed.

In this context, IUCN recently undertook a brief consultation process with practitioners and scientists across its networks as the basis for establishing an IUCN definitional framework for NbS. This framework includes three components: (i) the overarching goal of NbS, (ii) a definition of NbS; and (iii) a list of NbS principles. The articulation of these three elements will enable a coherent set of parameters, or standards, for NbS to be developed. The proposed articulations are set out below.

Overarching goal of NbS: NbS are intended to support the achievement of society's development goals and safeguard human well-being in ways that reflect cultural and societal values and enhance the resilience of ecosystems, their capacity for renewal and the provision of services. NbS are designed to address major societal challenges, such as food security, climate change, water security, human health, disaster risk, social and economic development.

NbS definition: NbS are defined as actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.

NbS principles: Based on our consultations, a list of preliminary principles was developed for NbS. To define that list, several existing frameworks were analysed (e.g., Ecosystem Approach and its principles, Ecosystem Services approach, the original list of principles for NbS in the 2013- 2016 IUCN Programme (IUCN, 2013) and others (Woodhouse et al., 2015).

A set of NbS principles, to be considered in conjunction with the NbS definition, will be essential in providing a full understanding of NbS for IUCN. The eight proposed NbS principles are as follows:

Nature-based Solutions:
1. embrace nature conservation norms (and principles);
2. can be implemented alone or in an integrated manner with other solutions to societal challenges (e.g., technological and engineering solutions);

3. are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge;

4. produce societal benefits in a fair and equitable way, in a manner that promotestransparency and broad participation;

5. maintain biological and cultural diversity and the ability of ecosystems to evolve over time;

6. are applied at a landscape scale;

7. recognize and address the trade-offs between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystems services; and

8. are an integral part of the overall design of policies, and measures or actions, to address a specific challenge.

1.3.4 Applying the NbS concept

NbS has been applied in a wide variety of sectors and to address a plethora of societal issues. NbS interventions can take many forms including, for example:

- Restoring and sustainably managing wetlands and rivers to maintain or boost fish stocks and fisheries-based livelihoods, reduce the risk of flooding, and provide recreational and tourism benefits;
- Conserving forests to support food and energy security, local incomes, climate change adaption and mitigation, and biodiversity;
- Restoring drylands to strengthen water security, local livelihoods and resilience to climate change impacts;

- Developing green infrastructure in urban environments (e.g., green walls, roof gardens, street trees, vegetated drainage basins) to improve air quality, support wastewater treatment, and reduce stormwater runoff and water pollution as well as improve the quality of life for residents;
- Using natural coastal infrastructure such as barrier islands, mangrove forests and oyster reefs to protect shorelines and communities from coastal flooding and reduce the impacts of sea-level rise.

A hypothetical scenario of an NbS is shown in Figure 3.1. This case illustrates two important points about NbS interventions: (i) they can complement other measures; and (ii) they can involve the use of natural areas or conservation measures that were originally established for a purpose other than that of the NbS.

This hypothetical case relates to a protected area in a coastal landscape. The protected area, originally created to provide an intact habitat for a particular rare species, is located near a watershed that is bordered by human settlements. In the past, flooding had not been a frequent problem as the forest and wetland had been able to absorb a large part of any storm surges. Over time however, deforestation and degradation of the forest and wetland ecosystems have left the expanding settlements more susceptible to flooding. The remaining forest in the protected area now plays a critical role in absorbing flood flows. In order to strengthen the ability of the protected area to perform this 'new' function and reduce flooding risk, it needs to be reconnected to the wider landscape to improve the entire watershed's functionality. The main NbS intervention – namely, restoration of the watershed, including the protected area – is therefore undertaken in combination with other NbS interventions (such as mangrove replanting and wetland restoration) and conventional measures (such as construction of a concrete flood barrier). Together these solutions not only mitigate flooding, but also support biodiversity and local livelihoods.

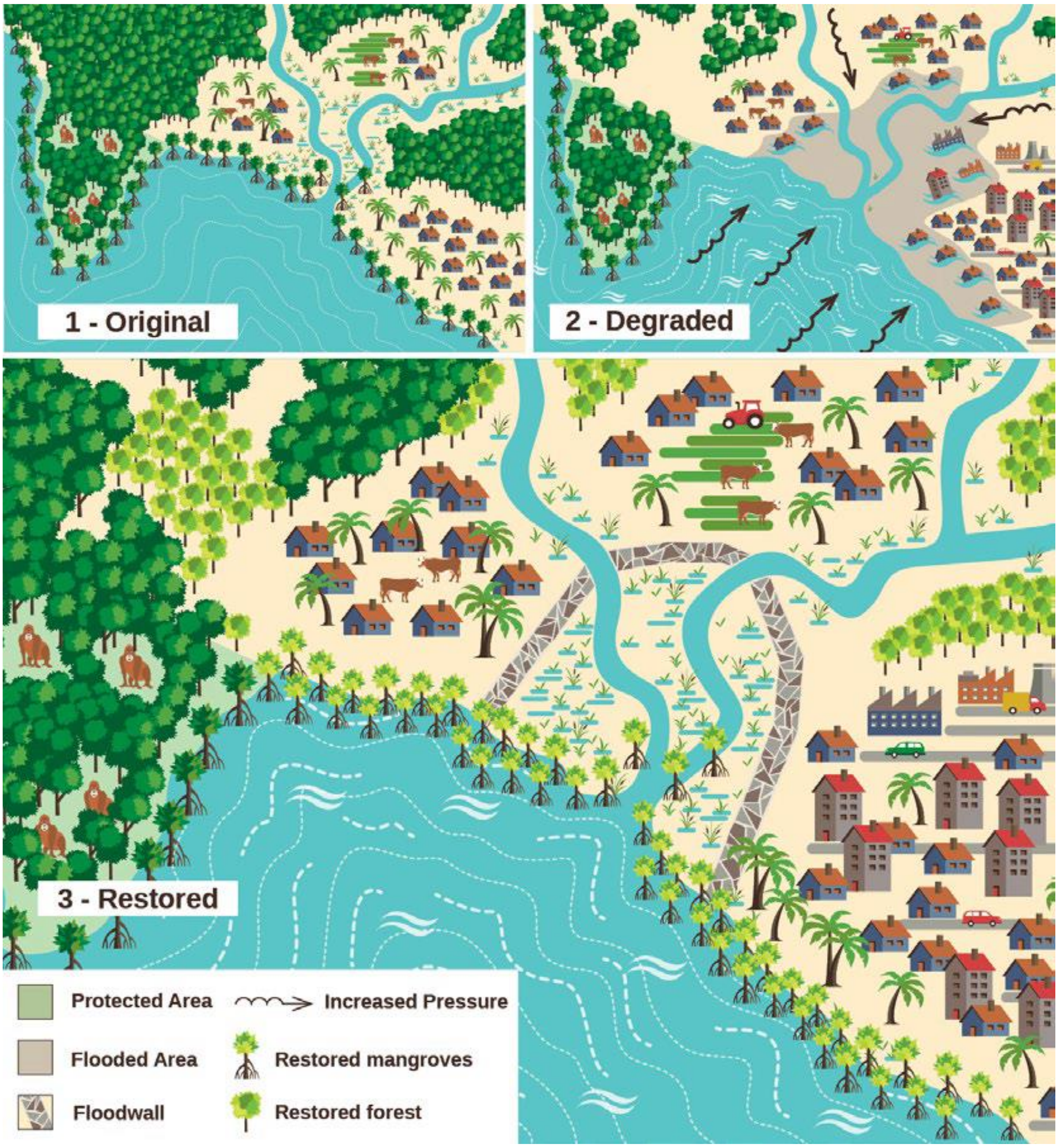

Figure 3.1. Hypothetical scenario of Nature-based Solutions being used in conjunction with infrastructure development and protected area conservation (Cohen-Shacham et al., 2019)

1.3.5 NbS for disaster risk reduction

Major disasters in the past decade have clearly demonstrated the role nature plays in reducing risks to natural hazards. Following Hurricane Katrina, the US Congress approved US$ 500 million for the restoration of its coastal national parks and salt marshes, following evidence that the parks and marshes had helped reduce the damage. Similarly, the Government of Japan declared the expansion of its coastal forests, in the form of the Sanriku Fukko Reconstruction Park, as these forests had helped reduce the impacts of the tsunami caused by the Great East Japan Earthquake in 2011 (Renaud & Murti, 2013).

These experiences demonstrate that the regulatory role of ecosystem services can be cost-effective in reducing risks posed to society by disasters. A study conducted by Swiss Reinsurance demonstrates that every dollar invested in protection of the Folkestone Marine National Park in Barbados can avoid US$ 20 million-worth of annual damages from hurricanes (Mueller & Bresch, 2014). Ecosystems such as wetlands, forests and coastal systems can reduce physical exposure to natural hazards by serving as protective barriers or buffers. Furthermore, such NbS can protect development infrastructure and property as well as support quicker recovery of livelihood sources. A study from Bhitarkanika Conservation Area in India, for example, shows that rice crops can take three times longer to recover from salt intrusion following coastal storms, without the presence of mangrove forests along the coastline (Duncan et al. 2014). Such learning from past events has led to the development of the ecosystem-based disaster risk reduction (Eco-DRR) approach.

It is important to recognize that a natural hazard event has the potential to turn into a disaster if the community or society is not able to cope with the impacts, using its own resources (UNISDR 2007). Disaster risk reduction efforts can significantly reduce the likelihood of a natural hazard event turning into a disaster "through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events" (Renaud et al. 2013). NbS such as the Eco-DRR approach can strongly support a community's risk reduction efforts. In the past two years there has been increasing recognition of this approach within global policy frameworks, namely the Convention on Biological Diversity (2014), The Sendai Framework for Disaster Risk Reduction (2015) and the Ramsar Convention on Wetlands (2015).

While the lessons learnt from past devastations have led to greater recognition of nature as a critical solution for disaster risk management, scaling up these NbS requires active facilitation of dialogues and capacity development amongst scientists, policy makers and practitioners of conservation and disaster management. NbS to disaster is addressed in part by SDGs 11 and 13 which focus respectively on making cities and human settlements safe and resilient and on mitigating and adapting to climate change. Through its implementation it also contributes to various SDGs such as SDG 1 (no poverty), 2 (no hunger), 3 (good health and wellbeing), 6 (clean water and sanitation) and 15 (life on land).

1.3.6 NbS for climate change

Climate change is one of the most pressing challenges confronting humanity today. Depending on how the world's ecosystems are managed, they can either contribute to the problem or provide effective Nature-based Solutions for climate change mitigation and adaptation.

First, NbS in the form of ecosystem-based mitigation (EbM) can make a powerful contribution in the fight against climate change by preventing the degradation and loss of natural ecosystems. Deforestation and forest degradation, for example, release an estimated 4.4 Gt of CO_2 per year into the atmosphere (Matthews & van Noordwijk, 2014), or around 12% of anthropogenic CO2 emissions (IPCC, 2014). When the land sector as a whole, including agriculture, forestry and other land uses (AFOLU), is considered, the contribution is about 24% of annual global anthropogenic emissions (ibid). Avoidance of these emissions, through better conservation and land management actions, is a powerful intervention that can make a significant contribution towards global mitigation efforts.

Second, natural and modified ecosystems can also make highly effective contributions in combating climate change through their function as a 'natural carbon sink' by absorbing and sequestering CO_2 emissions. Approximately 60% of cumulative anthropogenic GHG emissions since the pre-industrial era have been stored either on land (in plants and soils) or in the ocean (IPCC, 2014). Conservation, restoration and sustainable management of forests, wetlands and oceans thus plays a critical role in the healthy functioning of the carbon cycle and the balanced regulation of the planet's climate. It has been estimated, for example, that restoring 350 million hectares of degraded or deforested landscapes by 2030 can sequester 1-3 billion tonnes of CO_2e per year while also generating about US$ 170 billion per year in benefits from other ecosystem services, thereby making it a cost-effective NbS to climate change (New Climate Economy, 2014).

Finally, in addition to providing these direct mitigation benefits, ecosystems can also help vulnerable communities, especially those who depend on natural resources, to better adapt and become more resilient to the adverse effects of climate change, including extreme weather events and climate-related disasters, through ecosystem-based adaptation (EbA) and ecosystem-based disaster risk reduction (Eco-DRR). Such ecosystem-based interventions, or natural infrastructure, can complement and enhance the effectiveness of physical infrastructure such as sea walls and dykes in a blended, cost-effective manner.

It must be noted that for global efforts on climate change to be successful in keeping the temperature rise to well below 2 ºC, action from all sectors, across all levels and involving all actors, is required. But NbS are a fundamentally important part of this mix, and no long-term solution to climate change can be successful without fully drawing on them. NbS to climate change is also addressed in part by SDG 13 which focuses on climate change.

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Ch. 2 Best management practices review (Romania)

Ristea Oana, Constantin Alina and Cirstoiu Nicoleta

2.1 Introduction

One of the most ubiquitous and long-lasting recent changes to the surface of our planet is the accumulation and fragmentation of plastics (Barnes et al, 2009). Plastic is one of the inventions without which our households would not have been able to enjoy many innovations or comfort at affordable prices. Due to their lightweight, durability, and versatility, plastic is used in all fields of activity from packaging, construction, textiles, transportation, electrical and electronic machinery and industrial machinery. There is no branch of technology that does not use plastic and enjoys its benefits. In a short period of time, plastic replaced wood, glass, ceramics and metal.

According to the United Nations Environment Program report (2021), Drowning in Plastics - Marine Litter and Plastic Waste Vital Graphic, the life cycle of plastics includes the extraction of raw materials; design and production; packaging and distribution; use and maintenance; and final recycling, reuse, recovery or disposal. When a plastic component or plastic based good no longer works within the specified parameters which it has been designed for, it has reached its end-of-life. At this point it frequently becomes waste. Increasingly often, it turns out to be considered a valuable resource. However, there are still end-of-life options just using landfills for its disposal. Around the world, a huge number of plastic objects are abandoned or rejected without any concern about the consequences for the environment. Sources of plastic waste are multiple: sanitation and sewage, electrical components, automotive and air industries, commercial fishing activities, tourism, health care systems, construction, agriculture, and packaging, among many others (Santos et al, 2021)

2.2 Statistical data related to plastic and plastic waste

Global plastic production has risen exponentially over the last decades – now amounting to some 400 million tonnes per year (Plastic atlas, 2019). Approximately 9.2 billion tonnes of plastics have been produced since 1950. Only about 30% of these plastics remain in use, resulting in the generation of some 6.9 billion tonnes of primary plastic waste around the world to date (Geyer 2020). This plastic waste is made up of 81% polymer resin, 13% polymer fibres and 32% additives. In 2018 more than 343 million tonnes of plastic waste were generated, 90% of which was composed of post- consumer plastic waste (industrial, agricultural, commercial and municipal plastic waste) (Geyer 2020). As a result of this demand production of plastics has increased exponentially since 1950 up to 2018, and is forecast to double by 2050, to near 800 million tonnes annually (Fig.1). Also, by 2035 the accumulated amount of plastic waste in the earth system is predicted to equal the amount of fish in the oceans (Stubbins et al 2021).

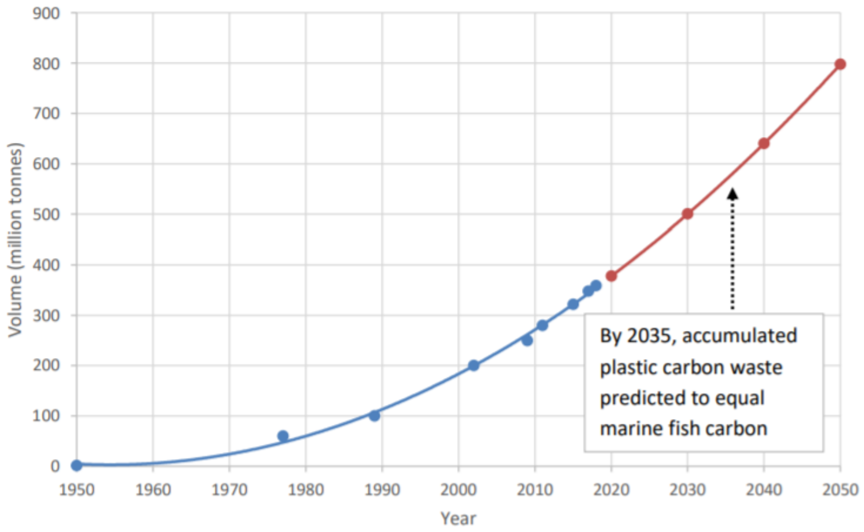

Figure 1- Global production volume of plastics. Blue line, production 1950 to 2018; orange line, forecast production 2020 to 2050. Data; 1950 to 2016 (Plastics Europe 2016); 2017-2018 (Plastics Europe (2019). Forecast 2020 to 2050, this study. Accumulated plastic carbon predicted to equal marine fish carbon stock (Stubbins et al 2021).

While plastics typically constitute approximately 10 percent of discarded waste, they represent a much greater proportion of the debris accumulating on shorelines. In the Plastic Atlas publication it is shown that in 2018, over 1,13 trillion items of packaging — most of them plastic — were used for food and drinks in the EU alone. Packaging is not the only problem: agriculture uses around 6.5 million tonnes of plastic worldwide each year. Plastic fuels climate change. If current trends continue, plastics will have caused around 56 gigatonnes of CO2 emissions by 2050.

2.3 Classification of plastic by origin and biodegradability

Association of plastics manufacturer in Plastics - the Facts 2020 mentions that today the most plastic materials are FOSSIL BASED and are produced from oil or gas. However, in the long term, plastics production should decouple from fossil feedstock. Which means that, in the future, the vast majority of plastics will be produced from alternative feedstocks, such as recycled oils or secondary plastics, responsibly sourced biomass, or even CO2.

According to European Bioplastics, a plastic material is defined as a BIOPLASTIC if it is either bio-based, biodegradable, or features both properties. EuRIC's Plastic Recycling Branch in "Plastic Recycling Factsheet" bioplastic is defined as:

a. Bio-based plastics are made from renewable resources instead of fossil fuels. For example, corn, wheat, etc.
b. Bio-degradable plastics can degrade by naturally occurring microorganisms such as bacteria, fungi, and algae.
c. Compostable plastics are biodegradable by naturally occurring microorganisms in a certified composting environment.

While the majority of bio-based plastics are recyclable by conventional processes, bio-degradable and compostable plastics are mostly non-recyclable, thus providing no added value in a circular econ-sses. Bio-based plastics does not necessarily mean the product is bio-degradable or compostable.

The OXO-PLASTICS OR OXO-DEGRADABLE PLASTICS are conventional plastics which include additives, to accelerate the fragmentation of the material into very small pieces, triggered by UV radiation or heat exposure. Oxo-degradable plastics were originally developed by EPI Environmental Technologies Inc. in 1991, with the aim to reduce environmental impacts of plastic in the open environment. The claim was that even when littered, oxo-degradable plastic fragments and biodegrades in the open environment without leaving any toxic residues or plastic fragments behind (EPI 2019). However, due to these additives, the plastic fragments over time into plastic particles, and finally microplastics, with similar properties to microplastics originating from the fragmentation of conventional plastics. The marine environment is where potentially most damage by plastic waste has arisen, including fragmented plastic and microplastics; at the same time, subsequent collection or recovery of the plastic is least probable (European Commission 2018).

2.4 Classification of plastic waste by sizes

Anthropogenic waste items and fragments occur in the aquatic environment in a wide range of sizes. They range from very large items (metres) down to particles and molecular sizes. For practical reasons, MSFD Technical Group on Marine Litter has classified plastic waste by size as follows:

- macro litter (>25 mm)
- meso litter (5-25 mm)
- micro litter (<5 mm)

Macroplastic is clearly visible plastic that can be caught, to say it in an easy way, and will not (with a few exceptions) have a direct impact on the food chain. Macroplastics are estimated to be one of the main sources of marine plastic pollution and secondary microplastics, and have direct negative effects on ecosystem health and human livelihood (van Emmerik, 2021). A European database of riverine floating macrolitter indicates that between 307 and 925 million litter items are released annually from Europe into the ocean (González-Fernández et al. 2021)

The term **"microplastic" (MP)** was formally introduced in 2004 by Thompson et al., who alerted to the growing problem of the plastic release to the seas. Since then, its presence in the environment has gained an increasing attention among the scientists, authorities, general population, and in the media. There are two types of microplastics:

(a) *Primary microplastics* are directly released into the environment as small plastic particles. These are intentionally engineered particles, like those found in some consumer and industrial products. Cosmetics have used microplastics as abrasives.

(b) *Secondary microplastics* are the result of the degradation of large plastic waste, like plastic bags and bottles, into smaller plastic fragments when exposed to our environment. Microplastics can be further degraded to nanoplastics, which have the particle size between 1 nm and 100 nm. The production of nanoplastics appears to occur rapidly in marine environments (Cózara et al. 2014).

2.5 The impact of plastic waste on the environment and human health

At the elemental level, plastics are predominantly carbon, and contribute to greenhouse gas emissions. The greenhouse gas (GHG) emissions from plastics would reach 15% of the global carbon budget by 2050 (Rouch D.,2021). United Nations Environment Programme (2021) shows in the paper "A global assessment of marine litter and plastic pollution" that aquatic organisms are continuously exposed to litter and plastic pollution. The largest, most persistent fractions of marine litter are synthetic polymers and thermosets, known collectively as plastics; these account for at least 85% of total marine waste. Contamination of the environment by plastics can occur due to transfer of (a) pre-fabrication plastic during transport, (b) single-use plastic materials after customer use of, food containers (including beverage bottles, straws, plates, solid food containers), other domestic products obtained in plastic packaging, (c) and plastic packaging after collection and during processing.

Litter can enter the coastal and marine environment from diverse point and non-point sources, which can be both land and sea-based. Detecting the source is fundamental for identifying targeted measures for each environmental medium. It is important to note that the pathways of land-based inputs can lead through different environmental media, and the im-pacts and behavior of plastics in each medium vary. In order to understand the effects better, further research is needed. If plastic leaks into the environment, it stays there for a long time and can take up to hundreds of years to break down. This causes damage, harms biodiversity and depletes the ecosystem services needed to support life. Plastic can enter nature in the form of either macroscopic litter or micro- or nanoplastics.

Macroplastic action on aquatic organisms both externally, causing damage and internally by ingestion. It is difficult to determine and quantify the causal links between mortality and ingestion of large plastic fragments, but there are growing numbers of investigations to better understand the origin of the plastics and the causes of death. Larger plastics that have made their way into the environment can slowly degrade or fragment into smaller pieces and eventually into microplastics.

The harm of micropalstic is not welldefined, which relates back to the high degree of diversity in microplastic assemblages, as well as several persistent knowledge gaps linked to the lack of validated analytical methods for analysing nanoplastic in a range of environmental samples. The diversity imparts an important control on the potential for a particle to generate negative impacts on a given organism, for example physical effects related to particle size or shape. One mechanism through which micro- and nanoplastics could present a hazard is in their role as a vector for other, toxic contaminants. (Singh J,*et al*, 2021). The potential harm that microplastics impose on ecosystems varies from direct effects (i.e., entanglement and ingestion) to their ability to sorb a diversity of environmental pollutants, like organic pollutants (POPs) such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and dichloro-diphenyl-trichloroethane (DDT), as well as trace metals (Menéndez-Pedriza, Jaumot, 2020)

Nanoplastic particles can enter the marine and fresh water food chains/webs via low trophic level organisms such as algae and bacteria, which then are predated by high trophic level organisms such filter feeders and fish. However, whether nanoplastics can enter human body through food chain/web and pose threats to human health still needs further exploration (Rouch D.,2021)

The effect on human health is as yet unknown, but plastics often contain additives, such as stabilisers or flame-retardants, and other possibly toxic chemical substances that may be harmful to the animal or human ingesting them. In addition to any risks from hazardous chemicals, the presence of microplastics and nanoplastics may pose risks to human health. It appears that at least some of the particles we swallow pass through the digestive tract and are excreted (Liebmann et al. 2018). However, ingested particles less than 2.5 µm in size can move through the epithelial layer of the gastrointestinal tract and into the circulatory system (Campanale et al. 2020).

2. 6 The plastic life cycle. The circularity of plastics

According with UNEP in „Drowning in Plastics”, the plastics life cycle includes extraction of raw materials; design and production; packaging and distribution; use and maintenance; and recycling, reuse, recovery or final disposal. This is a circular use of plastic in a circular economy. But most of the time, our "plastic economy" is currently linear. On a global scale, only 2% of the plastic produced is used circularly. PET-based soda bottles are a good example. Besides, some 8% is reused in lower value applications. These low percentages can be explained by the fact that no more than 14% of all discarded plastics are collected.

The transition to the circular economy shoud be made across the entire value chain in order to ensure circular design, production, use and waste management (Johansen *et al*, 2022). Developing a circular plastic economy and limiting plastic pollution require multilevel actions by different stakeholders. Among these stakeholders are waste management and other government authorities, chemical and plastic manufacturers, consumers and companies that produce consumer goods, retailers, waste management enterprises, plastic recyclers and others, including the informal sector (Hahladakis J.N. 2020).

In order to increase circularity, it is important to analyse the life cycle of plastics, from production to recycling and closing the loop. The use-phase is critical to understand its life cycle. Today, 60% of plastic products and parts have a use phase between 1 and 50 years, or even more. This is why, in a single year, the quantity of collected plastic waste does not match the quantity of production or consumption. Use of single-use plastics should be minimised, and replaced by compostable bioplastics where possible, combined with local bins that accept composable bioplastics. (Rouch, D. A, 2021)

The European Union's Strategy for Plastics in the Circular Economy (European Commission 2018) has set in motion a comprehensive set of initiatives, with business and governments responding to a challenge of serious public concern. These initiatives include increasing the uptake of recycled plastics and contributing to more sustainable use of plastics by implementing mandatory requirements for recycled content and waste reduction measures. Building circularity in support of sustainable consumption and production objectives across the life cycle of plastics means going beyond the 3Rs (Reduce, Reuse and Recycle), to 5Rs with Recover and Redesign (Thompson et al. 2009), and further to 7Rs with Refuse and Rethink (Ivar do Sul and Costa 2014; Ivleva et al. 2018).

2.7 Practices in plastic waste management

The production and disposal of plastics is responsible for significant greenhouse gas emissions and, when poorly managed, generates plastics pollution in the natural environment. According with **OECD (2018)** several approaches are available to address the environmental side effects of rapidly growing plastics production, use, and disposal.

• **Changes in product design**, such as through the use of alternative materials in the place of plastics, could reduce the production, use, and disposal of plastics in the first instance. Changes in design practices, such as through product light-weighting, could also help to prevent the generation of plastics waste. Shifting towards biobased or biodegradable plastics could reduce the adverse environmental impacts of plastics more directly by reducing their environmental footprint.

• **Better waste management systems**, by facilitating higher waste collection and recycling rates, would allow waste plastics to be captured before they begin creating problems in the natural environment.

• **Clean up and remediation activities**, such as stream bank clean-ups and technology to collect plastics from river, sea or ocean, would allow the removal of plastics already in the natural environment

2.8 Reducing the amount of plastic

2.8.1. Reducing the production of plastics from renewable materials

Plastics are made from fossil fuels, which contribute to increased greenhouse gas emissions and pollution. The best solution to this problem would be to avoid plastic production and use sustainable alternatives. This sustainable alternative is bioplastic.

Based on European Bioplastic Organisation bioplastics have several advantages. The use of renewable resources to produce bioplastics is the key for:

- increasing resource efficiency by the means of:
    - the resources being cultivated on an (at least) annual basis;

    - the principle of cascade use, as biomass can first be used for materials and then for energy generation;
- a reduction of the carbon footprint and GHG emissions of materials and products;
- saving fossil resources by substituting them step by step.

Biodegradable and bio-based plastics have been presented as potential alternatives to fossil fuel-based plastics, for example as food packaging. The main link between fossil-based plastics, bio-based plastics, and sustainability is that replacing fossil-based resources with biomass has a positive impact both on climate change and on how we handle waste (Molenveld K, 2020).

According to the latest market data compiled by European Bioplastics in cooperation with the nova-Institute, global bioplastics production capacities are set to increase from around 2.42 million tonnes in 2021 to approximately 7.59 million tonnes in 2026. Currently, bioplastics still represent less than one percent of the more than 367 million tonnes of plastic produced annually. Hence, the share of bioplastics in global plastic production will pass the two percent mark for the first time.

Bio-based content signifies the part or percentage of the product weight that is based on renewable resources. Some Bio-based plastic are natural origin with polymers that are extracted and sourced from biomass such as wood, corn, wheat, rice and potatoes. Examples include cellulose and starch. Biodegradable or bio-decomposable are plastics that can be degraded into carbon dioxide (CO_2) and/or methane by micro-organisms (such as bacteria and fungi). Whether a substance is biodegradable, depends on its chemical structure and the condition where degradation happens.

The persistence of bio-based and biodegradable plastics in aquatic habitats is uncertain but for some time experiments have found that even after three years the majority of biodegradable plastics and blends failed to show any degradation in the marine environment. There is evidence that, as litter, biodegradable plastics pose the same risks as conventional plastics to individuals, biodiversity and ecosystem functioning. For these reasons the general public should be adequately informed about the potential environmental impact of incorrect bioplastic bag disposal, is shown in the United Nations Environment Programme in 2021.

In cases where plastic waste is heavily contaminated with organic material (foodstuffs), fermentation with biogas reclamation is an excellent option where biodegradable plastics may offer advantages (Molenveld K, 2020). But in general, biodegradable plastics are biodegradable in a controlled environment such as a composting or fermenting plant. There are Bio-based plastic waste that is non-biodegradable for this reason must be processed in the same way as petrochemical polymers. There are currently no specific directives in the EU to promote the use of bio-based plastics and chemicals. In contrast, in the United States of America, throught 'Bio-preferred' programme, bio-based products are prefered over traditional plastic products in the federal procurement programme.

2.9 Reduction of plastic waste

The large amount of plastic waste can be reduced by:

a. Minimising use

Resources, energy, water and fabrication stocks, can be conserved by minimising use of plastic materials, especially single-use plastics. Consumers have a major role in reducing the use of plastics in general shopping packaging, food and beverage packaging and bathroom products (Rouch,D.A., 2021). A good example for prevention of packaging waste is Italy, through the initiative Eco-Point for selling bulk commodities.

b. Reuse

Reuse extends product and material life-cycles, to reduce the waste stream. Innovative reuse models can unlock significant benefits, enabled by digital technologies and shifting user preferences. Consumers are encouraged to use reusable containers for water and food. Good practices consist of extracting of reusable products from waste flow and introduce them in reuse systems, usually through second-hand shops, repair shops, flea markets or charity markets (Violeta-Monica Radu et al 2019).

c. Recycling

Recycling is only the second best way to cope with the ever faster growing plastic. Only one-third of the total plastic wastes generated are suitable for recycling, based on their material composition (Chamas *et al.*, 2020). Polypropylene (PP), polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC), *etc*. are some of the recyclable plastics.

However a typical household waste stream may contain a variety of plastics in the form of packaging, carrier bags, bottles, plastic lids, and food and household containers. Not only are these plastics mixed they are also contaminated with items such as food waste, residues, labels and glue. Plastics may be mixed with other materials such as aluminium linings or metal closures. Depending on the quality and purity of the waste, the priority should therefore be given to reuse, then reprocessing (mechanical recycling), then depolymerization to the monomer, then conversion to a hydrocarbon feedstock and, as last resort, energy recovery (Lange, 2021).

There are several techniques for recycling plastic. The most common method of recycling is called mechanical recycling. If mechanical recycling is not possible, then chemical recycling and finally energy recovery both present viable alternatives to offset the usage of oil reserves in the creation of the plastic material (Goodship V., 2007). However the best way of waste disposal will always ultimately remain one of waste minimization through best practice by both manufacturers and the general public ensuring maximum environmental benefit.

Mechanical recycling-Plastics can be subdivided into two main categories: thermoplastics and thermosets. This distinction relates to the basic molecular structure and affects which processing route as well as which recycling route can be applied. The reason why thermoplastics and thermosets need to sort each other out is that thermoplastics cannot be remelted to reprocess them. Mechanical recycling is done through a melting process only for thermoplastics.

Recycling route for termoplastics may be split into two types of processes: physical methods to homogenize the waste (i.e. storage, shredding, washing and sorting) and melt processing (i.e. re-granulation and reprocessing). Thermosets are cross-linked, meaning they cannot be re-melted and re processed in the same way as thermoplastics. One possible use for thermosets is as a filler material for thermoplastic materials.

Chemical recycling is a process where the polymer is broken down into smaller molecules that can be easily separated from impurities.

Thermal processing can be defined as the conversion of solid wastes into conversion products with a release of heat energy There are a number of different categories usually distinguished by their air requirements.
1. Pyrolysis: thermal processing in absence of oxygen.
2. Hydrogenation: pyrolysis but in a high hydrogen or carbon monoxide environment.
3. Gasification: partial combustion in which a fuel is deliberately combusted with limited air.

Plastic waste presents an opportunity for producing profit, through the generation of high calorific fuel resulting from the pyrolysis process (Singh et al., 2021).

Compared to simply burning polymeric materials by combustion, these methods can offer significant benefits (Goodship V., 2007).

- Environmentally cleaner process routes producing significantly lower emissions.
- The reduction in density enables cost reduction for subsequent transport and handling
- Increased energy density
- Conversion to fuel results in higher overall efficiencies than standard combustion.

There is one type of plastic that is recycled at a higher rate than others – HDPE plastic. It's considered to be the safest and most cost-efficient plastic to recycle. The second most common is PET.

d. Reprocess

Waste plastic may be converted into value-added materials or chemicals. Recycled plastic can turn into products such as clothing, furniture, and new plastic bottles.

2.10 Legislative requirements at European and national level

The European Strategy for Plastics in a Circular Economy (EC, 2018a) notes that plastic recycling is not at the same pace as increasing global plastics production. Currently, in Europe, only 30 % of plastic waste is collected for recycling. The plastic waste that is collected but not recycled is landfilled or incinerated. Both plastic production and plastic waste incineration contribute significantly to the generation of greenhouse gas emissions (Preventing plastic waste in Europe, 2019). All waste prevention programmes include measures that either directly address plastic waste prevention or are horizontal measures that also refer to avoiding plastic waste.

At EU level, about a quarter of post-consumer plastics are being recycled, a third recovered in waste-to-energy processes and the rest landfilled. According to Association of Plastics Manufacturers in Europe end-of-life plastic management in 2018 in some european countries are:

- In Germany: 5.3 million tonnes of plastic post-consumer waste were collected through official schemes in order to be treated. From 2006 to 2018, the volumes for recycling increased by 80%, energy recovery increased by 73% and landfill decreased by 80%.
- in UK: close to 4 million tonnes of plastic post-consumer waste were collected through official schemes in order to be treated. From 2006 to 2018, the volumes for recycling

increased by x2.4, energy recovery increased by x6.8 and landfill decreased by 66%.
- in Italy: 3.6 million tonnes of plastic post-consumer waste were collected through official schemes in order to be treated. From 2006 to 2018, the volumes for recycling increased by 68%, energy recovery increased by 57% and landfill decreased by 48%.
- in France: 3.6 million tonnes of plastic post-consumer waste were collected through official schemes in order to be treated. From 2006 to 2018, the volumes for recycling increased by 79%, energy recovery increased by 35% and landfill decreased by 18%.
- in Spain: 2.5 million tonnes of plastic post-consumer waste were collected through official schemes in order to be treated. From 2006 to 2018, the volumes for recycling increased by x2.3, energy recovery increased by 59% and landfill decreased by 41%
- in Poland: 1.9 million tonnes of plastic post-consumer waste were collected through official schemes in order to be treated. From 2006 to 2018, the volumes for recycling increased by x2.7, energy recovery increased by x115 and landfill decreased by 21%
- -in Netherlands: 0.9 million tonnes of plastic post-consumer waste were collected through official schemes in order to be treated. From 2006 to 2018, the volumes for recycling increased by 79%, energy recovery increased by 15% and landfill decreased by 97%.
- In Belgium: 0.6 million tonnes of plastic post-consumer waste were collected through official schemes in order to be treated. From 2006 to 2018, the volumes for recycling increased by 56.7%, energy recovery increased by 36.7% and landfill decreased by 83.6%.

The European Union introduced the first packaging waste management measures in the 1980s, establishing a set of rules for the production, marketing, use, recycling and reuse of containers for liquids for human consumption, but also for the disposal of used containers. Subsequently, in order to meet the requirements of environmental protection, some Member States have introduced their own measures in this area. Thus, there has been a need for legislative harmonization at European level, resulting in the adoption in 1994 of **Directive 94/62/EC on packaging and packaging waste**. This Directive aims to provide a high level of environmental protection and to ensure the functioning of the European internal market for packaging (Violeta-Monica Radu et al 2019).

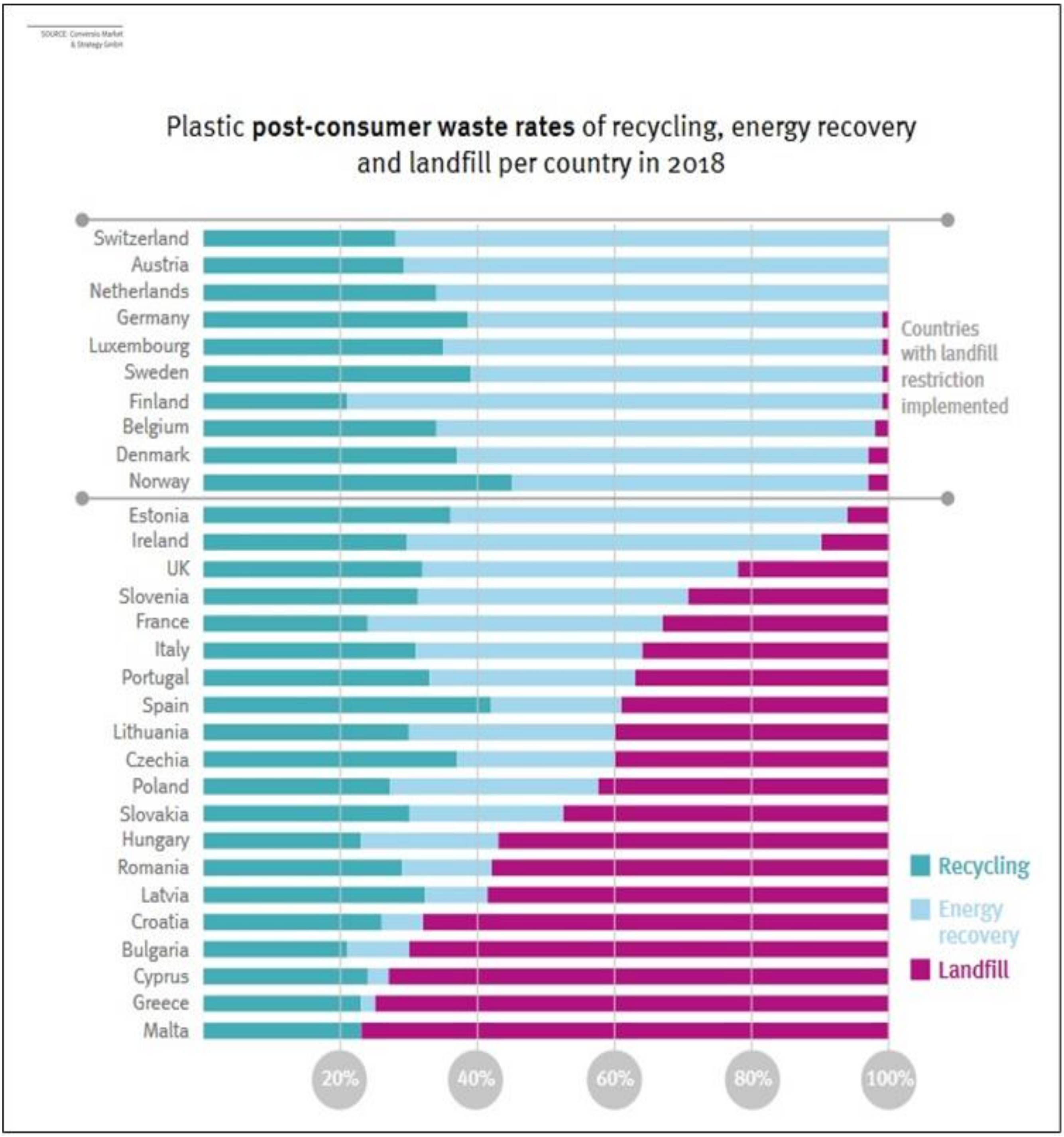

Figure 2. Plastic post consumer waste rates of recycling, energy recovery and landfill per country in 2018. Source: Plastics Europe. Plastics – the Facts 2019.

In 2004, the Directive was amended, setting out criteria for clarifying the term of packaging and increasing targets for the recycling and recovery of packaging waste. The Directive has been revised several times (2005, 2013, 2015). The 2015 revision was driven by the adoption of **Directive (EU) 2015/720 on the use of disposable plastic bags**. This was the first legislative outcome of this public consultation concerning plastics and imposes the reduction the consumption of lightweight plastic bags by the European Commission. Light weight plastic bags are carriers with a thickness below 0.05 mm.

The directive was proposed in November 2013 and passed by the European Parliament in April 2015. Member States were to transpose it into their national legislations by 27 November 2016, and introduce measures to achieve the still modest but vital reduction objectives of 90 bags per person per year by 31 December 2019, and 40 bags by 31 December 2025. As a result of this directive, traders can no longer provide customers with light (less than 50 microns) and very light (less than 15 microns) plastic bags free of charge, except for very light plastic bags for hygiene or for the primary packaging of bulk food. Another common measure is to set a tax for each bag purchased. The aim was to reduce consumption and the adverse effects plastic bag litter had on the landscape.

The EU Single-Use Plastic Directive 2019/904 promotes circular approaches that give priority to sustainable and non-toxic re-usable products and re-use systems rather than to single-use products, aiming first and foremost to reduce the quantity of waste generated. According with these EU Directive single-use plastic products are typically intended to be used just once or for a short period of time before being disposed of, as against plastic products that are conceived, designed and placed on the market to accomplish within their life span multiple trips or rotations by being refilled or re-used for the same purpose for which they are conceived.

The Single-Use Plastics Directive, assembled in 2018 by the European Commission, concretises the ambitions on the reduction of marine litter, based on a list of the 10 most common plastic objects found on beaches (which together constitute 70 percent of all marine litter items), and fishing gear containing plastic. The 10 items being addressed by the Directive are: Cotton bud sticks, Cutlery, plates, straws and stirrers, Balloons and sticks for balloons, Food containers, Cups for beverages, Beverage containers, Cigarette butts, Plastic bags, Packets and wrappers, Wet wipes and sanitary items.

Under the directive measures include:

- A ban on selected single-use products made of plastic for which alternatives exist on the market: cotton bud sticks, cutlery, plates, straws, stirrers, sticks for balloons, as well as cups, food and beverage containers made of expanded polystyrene and on all products made of oxo-degradable plastic.
- Measures to reduce consumption of food containers and beverage cups made of plastic and specific marking and labelling of certain products; The label must inform consumers of appropriate waste management options for the product or waste disposal means to be avoided, as well as of the presence of plastics in the product and the negative impact of littering. (Art. 7, para. 1 in conjunction with annex, part D.)
- Separate Collection Targets and Design Requirements for Plastic Bottles for a 77% collection target for plastic bottles by 2025, and 90 % by 2029; the introduction of design requirements to connect caps to bottles; a target to incorporate 25 % of recycled plastic in PET bottles from 2025 and 30 % in all plastic bottles from 2030.
- Extended Producer Responsibility schemes to cover the cost to clean-up litters
- Awareness Raising-the directive requires that EU member states incentivize responsible consumer behavior and inform consumers of reusable alternatives, as well as of the impacts of littering and other inappropriate waste disposal on the environment and the sewer network (Art. 10.).

Also, the Directive contains a number of recommendations:

1. Production of plastics is to utilise renewable sources, and phase out use of fossil fuel feedstocks.
2. The lifecycle of plastic products, including recycling, should be considered at the design phase. Also, the design should aim to minimise the amount of plastic used.
3. Food services are to prefer compostable bioplastics; plates, cups, cutlery and straws: to reduce use of single-use non-bioplastics.
4. Packaging materials that are difficult to recycle are to be phased out of production and use. In particular, PVC, EPS and oxo-degradable plastics are to be phased out.
5. Robust after-use systems are to implemented, to efficiently reduce leakage and optimise reuse and recycling of plastics.
    - o To standardise collection options across a state or nation, to support improved efficiency of recycling.
    - o To include commercial composting systems to process compostable bioplastics.

o Three plastics; PET, HDPE and LDPE are to be recycled, while PP bottles can be reused.

6. Minimising leakage of plastics to the environment is to be considered at each stage of the plastic lifecycle

▪ Use of single-use plastics should be minimised, and replaced by compostable bioplastics where possible, combined with local bins that accept compostable bioplastics.

7. For each country, an integrated national strategy for waste recycling, including plastics, must be developed and implemented, with leadership by government and industry, and with attention to supporting the circular economy.

Another issue related to the presence of plastic waste is the presence of **microplastic**. The MPs used in cosmetics is the most important source of primary MPs to the environment (Yolanda Picó, Damià Barceló, 2019). There are some legislative measures already in force in order to decrease MP release. Since 2017, US already banned the used MP beads in the cosmetics products. Many other countries including Australia and Canada are also thinking in implementing effective measures in the same sense. Based on the conclusions of the European Chemicals Agency, the **European Commission will impose restrictions on the use of microplastics in various products**. This restriction will have an impact on the cosmetics industry. Adoption of this new legislation is most likely to take place in 2022. Transitional periods are granted, with the exception of cosmetic exfoliating microplastics, which will be banned as soon as the regulation is implemented.

The European Union is introducing a levy on non-recycled plastic packaging waste from 1 January 2021, levied through EU member state contributions. The amount owed by each member state will be calculated according to the weight of non-recycled plastics packaging placed on each member state’s market. The rate will be €0.80 per kilogram (€800 per metric ton). Each member state can choose how to finance this levy, whether by directly taxing the plastics sector, or through other methods of taxation. All European countries must transpose European directives on plastics into national law.

If in terms of plastics management directives most European countries have implemented the requirements in national legislation, regarding Single-Use Plastic Directive the situation is different. In the report „Moving on from single use plastics: how are EU countries doing?”, the authors assessed the performance of all EU Member States in transposing the Single-Use Plastics Directive into their national law, highlighting for each positive developments, missing measures, main issues and informing on the national process. This assessment shows that only a few countries have fully explored the potential offered by the Single Use Plastics Directive to phase out single-use plastics and effectively prevent plastic pollution. A majority of countries have adopted the bare minimum requirements to comply with the Directive or are missing some of the measures (e.g. related to EPR) to be adopted. In many countries, the transposition process is still in progress or has barely started.

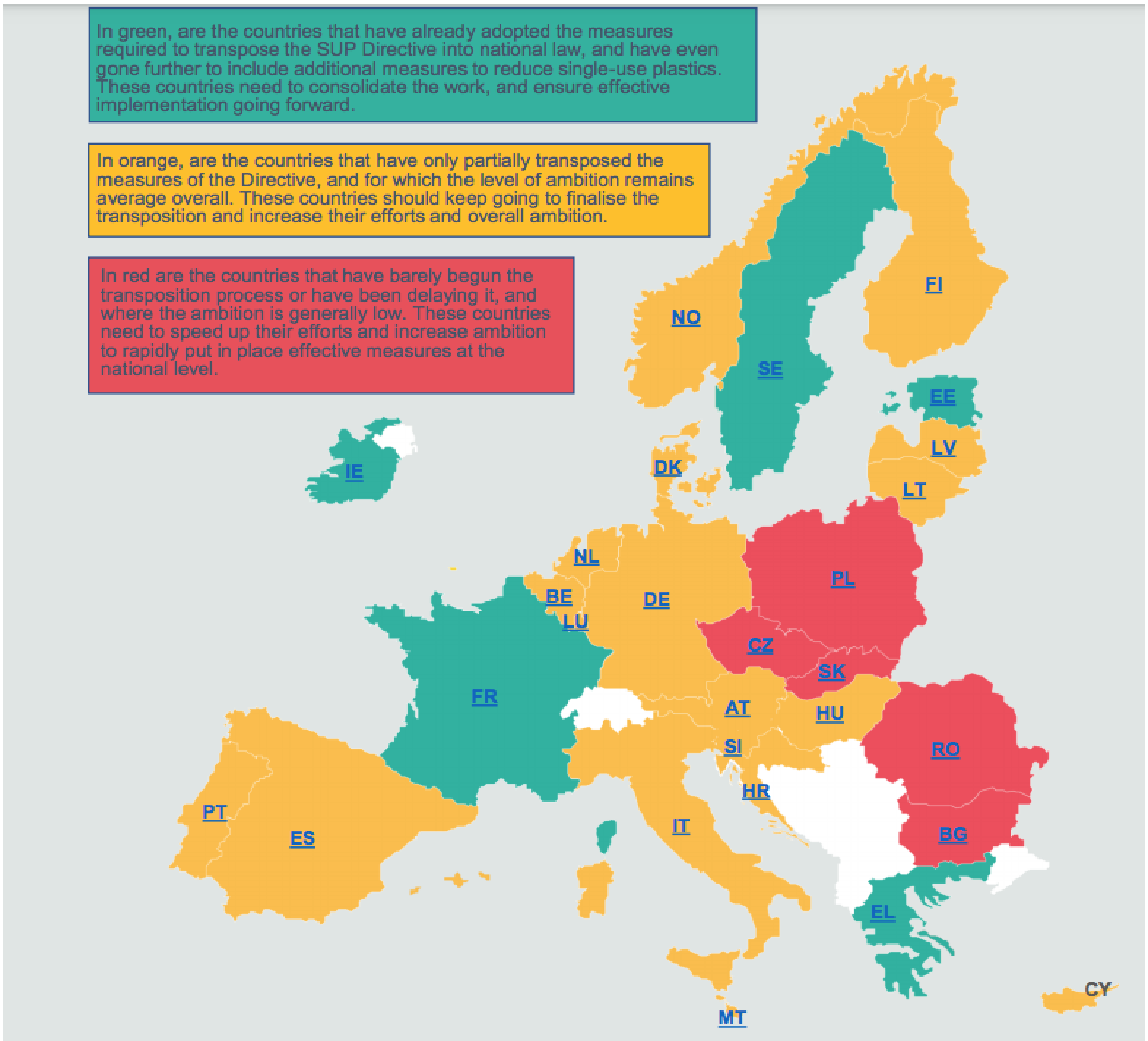

Figure 3. The performance of all EU Member States in transposing the Single-Use Plastics Directive into their national law (Source Report EU „Moving on from single use plastics: how are EU countries doing?”).

2.11 Good practices in waste management

A good waste management must be based on the 3Rs hierarchy: reuse, recycling, recovery. These actions reduce the amount of plastic waste, but also the amount of plastic produced. Waste prevention refers to practical actions that reduce the quantity of materials prior to materials and products becoming wastes. Waste prevention is therefore fundamentally different from waste management activities, as waste management activities are implemented after materials become waste.

2.11.1. Reduce, Reuse, Refilling, Refuse, Return

REDUCE the among of plastic waste includes REUSE/PROLONGING USE – extending product life, serving as a diversion of waste flows and REFUSE/RETHINK/AVOIDANCE – eliminating the need for a product or material.

REUSING means that the packaging is not changed in form or structure but is simply reused as it is - usually after being washed. Reuse si the core idea of a circular economy. Thus the reuse is achieved through another good practice, REFILLING. The refill models include:

1. Refill at home – users refill their reusable container at home
2. Refill on the go – users refill their reusable container away from home at an in-store dispensing system.

In France, there is a legislative initiative to support the purchase of bulk products. Every consumer now has the right to be served using their own container, as long as it is clean and adapted to the nature of the product purchased. To reduce public dependency on plastic bottles, drinking water fountains in public places, including schools, will become obligatory, and restaurants will be compelled to offer free still water to their clients. However, as no consensus was found on refundable bottles, the public will have to wait until 2023 before a system mixing recyclability and reusability of plastic and glass bottles is established, dependent on evaluation results.

Another good practices for reducing the among of plastic waste is REFUSE to use single-use plastic, choose a reusable or recyclable product instead, or the product is delivered to the consumer without the use of packaging. According to FAWCO's Environment Team, „the simplest way forward is to start by refusing plastic as much as we can. Refusing plastic should be the first approach, and it's really all about awareness". RETURN is a actions through the consumer returns the packaging to the store. The deposit-return system ("DRS") for both reusable and single-use bottles saves raw materials, energy and CO2 emissions, because it reduces the fossil fuels used to produce new bottles.

Deposit Return Schemes (DRS) as a key way of reducing the production of single-use packaging waste. The mechanism is simple: encourage consumers to return empty bottles and containers by asking for a small additional payment at the point of sale, which they get back upon returning the empty packaging. The solution is a win-win for everyone, but it has not always been easy to implement.

Deposit Return Systems are already active in 10 European countries, and 12 additional countries have voted in favour of legislation to introduce similar schemes by 2022 or 2023. Nine countries are discussing what type of deposit system to adopt, and how it should be organised. Only the Czech Republic, Bulgaria, and Italy have not yet started a debate regarding the introduction of DRS on their territory.

Europe’s first Deposit Return Scheme was introduced in Sweden in 1984. In 2002, Germany adopt a bottle deposit scheme. All stores in Germany that sell beverages are required to take them back and return the deposit (pfand) to the customer – whether or not that person bought that beverage from them. The system launched in Lithuania in 2016 is considered one of the best in the world, leading to the recovery of 70% of drinks containers in its first year, and 90% in the second year

As of 1 October 2022, Romanian consumers will have to pay a mandatory deposit of RON 0.50 (approx. ten Euro cents) for each bottled beverage they buy. Other patterns of Rs have also been designed for circularity, such as Repair, Rent and Resell (Gillabel *et al*. 2021). Encouraging the practices for reducing the amount of plastic waste is achieved by raising public awareness and by creating facilities for it.

2.11.2. Recycling and separate collection of plastic waste

Plastic recycling rates remain low and stagnant across the globe, with vast volumes of plastic being disposed of and leaking into nature. WWF throw initiative call „Plastic smart city” establishes that financial incentives designed to persuade households and waste producers to reuse and recycle more, helps prevent the generation of waste and can help contribute to financing waste management activities. Incentives include both rewards and charges (pay-as-you-throw PAYT, and deposit refund schemes). Rewards are given to the users to encourage people to recycle more, typically with vouchers for individuals, vouchers for communities or payments to individuals. In addition to direct incentives in the form of vouchers, an effective recycling incentive is also the reduction of waste fees for residents willing to separate more waste at source, or when waste recycling targets at local level are achieved.

2.11.2.1. Separate collection and sorting

Separate collection and sorting is the most important stage in recycling process and in the life cycle of plastic. The success of the waste management policy is based on good sorting practice by the largest number of citizen (Dupre, 2016). Over the years, waste sorting has become the most widespread ecological gesture in the population (Dupre, 2016)

In "A European Strategy for Plastics in a Circular Economy", more and better plastic recycling is held back by insufficient volumes and quality of separate collection and sorting. The latter is also essential to avoid introducing contaminants in the recycling streams and retain high safety standards for recycled materials.

European legislation considers public access to waste collection services, followed by mandatory separation of waste at source and dedicated collection points for small plastic items to be key elements for successful waste management. For each country, an integrated national strategy for waste recycling, including plastics,must be developed and implemented, with leadership by government and industry, and with attention to supporting the circular economy.

The main objective of a collection strategy is to implement collection of waste separated at source, as correct as possible, in order to ease subsequent sorting and treatment, aiming to maximize waste recycling.Then, each local authority must decide on the most appropriate strategy for their area and residents, and under local conditions. Best practices municipal solid waste collections are typically implemented via door-to-door or kerbside collection rounds from household and businesses, when appropriate within a pay-as-you-throw system, or at municipal waste collection centres (Dri M, 2018).

The first step is the collection of waste by source-collection (by consumers) or post-separation (in centers). Source-collection is preferred because it is cheaper and reduces contamination of waste. (Prata,J., 2019). The most appropriate collection strategies will depend on the characteristics of the collection zone (e.g. densely populated urban areas versus sparsely populated rural areas) and public acceptability of various strategies:

Source separation of waste streams by householders

a. Door-to-door - Within door-to-door collection systems the bins/sacks can be collected from the doorstep of the inhabitants, but also by kerbside collections. Sorting waste fractions at home for a door-to-door collection system proves to positively affect the environmental impacts of waste management strategies both by reducing the amounts of the waste landfilled and by originating new circular economies. (Laurieri, 2020). At this level the sorting can be done in at least 3 fractions: recyclable, biodegradable and mixed waste. But you can make a selection of recyclables by categories (paper, glass, plastic, metal, etc.)

b. Bring banks for large waste objects or for the collection of glass (mostly separate for white and coloured glass).

Bring systems can be complementary to door-to-door collection and they may target specific materials that are not covered by door-to-door collection.

2. Source separation of waste streams by municipalities

Civic amenity sites or recycling centres are typically enclosed and sometimes staffed collection sites that are used as additional collection systems, usually accepting the same streams as collected in the door-to-door and bring point collection but also additional streams such as hazardous waste, garden wastes, and WEEE. Often civic amenity sites are operated by the municipalities themselves. Citizens can bring their waste there, which may or may not be free of charge.

3. Deposit and refund systems are typically applied for beverage bottles (cans) made of glass or plastic (metal) and are in most cases systems established at national level, e.g. by an EPR scheme.

4. Pay-as-you-throw: special garbage bags or tags/stickers are purchased and non-compliant bags are not collected through the scheme; In Belgium The Pay as You Throw (PAYT) schemes have been fundamental in compelling the public to adhere to the sorting of waste regulations. Residents are given about 4 bags to sort their waste in their homes. The bag of waste meant for disposal, costs more than the bags for recyclable waste. Residents are also given a waste collection calendar yearly or they can download the Recycle mobile application since collections for different coloured bags maybe carried out on different days. Residents are also fined if they do not sort or leave an improperly sorted bag in the street (Simon, J, 2015)

2.11.2.2. Best plastic waste management - local jobs opportunities

The study, "More Jobs, Less Pollution" shows that a 75% national recycling rate would create nearly 2.3 million jobs while reducing pollution by 2030. There are numerous local, national and international industries that depend on recyclable materials. When you choose to recycle your discards, jobs are created in:

1. **Collecting, processing and preparing materials.** Your discarded materials are picked up and then brought to processing facilities where they are sorted and prepared to sell to markets.
2. **Making new products from recycled materials (manufacturing).** Your recyclables then head to manufacturing facilities that use recycled feedstocks, such as paper mills, metal smelters and plastic manufacturing facilities. Compost facilities turn your discarded yard and food scraps into valuable soil amendment.
3. **Reuse and remanufacturing.** Some discards are sorted and fixed up to be used again through computer refurbishers, thrift stores and auto salvage yards.

2.11.2.3. Awareness and education of the population

National, regional and local authorities, in cooperation with waste management operators, have a key role to play in raising public awareness and ensure high-quality separate collection. Best practice in awareness-raising is to effectively encourage waste prevention, reuse and recycling behaviour within the waste collection catchment area. Ultimately, this should translate into improved performance across key waste generation and separation indicators. Recycling education is necessary to increase the amount of waste recycled as recycling programs and methods evolve over time and it is important for people to understand how recycling programs operate. Understanding the processes involved with recycling will allow people to fully utilize recycling programs (Bennett,E.M, 2021).

It is crucial that whatever collection strategy is in place is clearly conveyed to citizens so that they know what to put in which bins/sacks, and when to leave them out for collection household calendars of collection dates are useful to remind citizens when to put out bins for collection. The public should be educated on the different plastic recycling codes. Investment in awareness campaigns is necessary and these must reach as far as informal settlements and rural areas. It was noted that rural households are less likely to recycle as compared to urban households (Mazhandu, 2021)

The two European strategies concerning plastics (Directive (EU) 2015/720, Directive 2019/904) include awareness raising measures, but, on the other hand, education institutions are not specifically mentioned as actors to achieve goals. To accelerate the transformation process towards a more sustainable future, educational institutions need to be actively incorporated into awerness process and the education for sustainable development needs to be strengthened (Kerscher, 2019).

In order to achieve the objectives of waste management, it is necessary to take measures as follows:

- Information and awareness campaigns as an important tool in environmental
- education, needed to understand environmental issues;
- Involvement of the population representing an important process in integrated
- waste management, in that it can lead to decision making accepted by the parties,

communication being essential for obtaining positive results.

An information campaign on the importance of selective collection contributes to the successful implementation of what was originally planned. In order to achieve the proposed objectives, they need to be realistic, achievable.

The information and awareness campaigns for the population aim at:

- Sustainable and efficient management of natural resources;
- Reducing health problems caused by poor waste management;
- Observance and understanding of the legislation in the field and implicitly its observance;
- Increased understanding of the waste management process, especially related to waste reduction and recycling.

4.11.2.4 Examples of good practice

Zero Waste Cities is the **Zero Waste Europe`s Programme** dedicated to help cities and communities transition towards zero waste. It brings together a European platform of knowledge for local stakeholders to implement best practices, as well as a mentoring and recognition programme for municipalities. Zero Waste offers free advice and support to local communities in the transition to better waste management and reducing by over 90% the amount of waste stored in landfills. Zero Waste mission is to facilitate the transition to a circular economy. From point of viw of Zero Waste Europe waste is a resource that can be reused.

ROMÂNIA- Sălacea city

The city of Sălacea, located in northwestern Romania, managed in 3 months to increase the percentage of waste recycling from 0% to 40% as well as reducing waste in general by 55%. In partnership with Zero Waste Europe and Zero Waste Romania, the authorities in Sălacea have started to create a sustainable waste management system:

- a complete door-to-door separate collection system on five streams, including biowaste
- engagement of local operator for a sorting and treatment plant
- a comprehensive four weeks education programme and a strong communication strategy to engage the community

After only 3 months the results were outstanding:
- Total waste generated fell from 106.7 tonne to 47.93, a drop of 55%.
- Waste that went to landfill dropped from 105 tonne (98%) to 26.3 (55%)
- Separately collected waste rose from 1% to 61%,
- Rates of local citizen engagement increased from 8.4% to 97%

SPAIN- Pontevedra Province

The Spanish province of Pontevedra, which includes 61 northern municipalities, had for a long time extremely low waste management results with only 9% of its waste being separately collected, leaving the remaining 91% to be transported more than 100 kilometres away to be either burned or landfilled. To shift from this unsustainable, centralised and expensive waste management system, and to comply with the EU recycling obligations, the province launched a project named "Revitaliza" which built a decentralised, community-led composting system for biowaste relying on 3 key factors:

1. A suitable location for the composting process to be conducted at, which has been adapted to the area's specific needs and context
2. The design and implementation of an effective monitoring system to ensure the success of the process, by identifying and solving issues that arise throughout the implementation phase
3. A strong communication plan

In 2019, after only 3 years, the Province achieved ambitious results:
- More than 2,000 tonnes of biowaste were locally composted
- The project rolled-out in more than two-thirds of the province's municipalities

FRANCE- Besançon city

Besançon and its surroundings have a population of 225,000 people of whom half is living in densely populated areas. Before 2008, waste was incinerated in the incineration plan which had 2 furnaces, one of them built in 1975 and therefore obsolete. That was the starting point of the waste management revamping to make it more sustainable. The political choice not to rebuild an incinerator entails need to both waste prevention and residual waste reduction.

Three main measures were taken:
- Implementation of a Pay-As-You-Throw system (PAYT)
- Adoption of a waste prevention plan (-15% of residual waste over 5 years)
- Development of a decentralised composting system

Now, more than 10 years after the starting point, it paid off:
- Total waste generation went from 531kg/cap in 2000 to 464kg/cap in 2017
- Residual waste has been reduced by 77 kilograms between 2008 and 2017
- In 2016, more than 7400 tonnes of organic waste were composted leading to save around 800,000€ of waste management costs

CROATIA- Prelog city

The city of Prelog in northern Croatia has tripled the percentage of its separately collected waste. The city has reduced the amount of the mixed waste local residents produce to below 100 kg per capita, becoming a zero waste best practice in Croatia and beyond.

How did this happen, in spite of much criticism saying the set goals were unattainable and 'utopian' for the Croatian context?
- Door-to-door separate waste collection
- Construction of new local waste management infrastructures
- Create a fair but profitable system
- Effective education & communication programmes for citizens
- Strong cooperation between the NGO Zelena akcija / Friends of the Earth Croatia /

Zero Waste Croatia, the city of Prelog, and 11 other neighboring municipalities (of different political affiliations) operated by the public company PRE-KOM from Prelog.

2.12 Conclusion

In order to reduce the impact of pollution with plastic waste, pollutants with a long life, a series of good practice measures are needed, which refer both to the consumer and to the local authorities. In this review, a series of actions were mentioned, some imposed by the legislation in force, but also those related to consumer education.

Table 1. Good practices as related to the activities.

Good practices	Activity
REUSE	reuse old plastic bags for multiple shopping trips
	reduce your use of disposable shopping bags by using a reusable bag or container when shopping
	reuse plastic objects instead of throwing them away in storage containers
	purchase items secondhand (exemple plastic toys, clothes)
	donate slightly used plastic items
	pack lunches with reusable containers
REFILL	refill water bottles
	installation of drinking water sources on the street
	buy products in bulk to refill plastic containers(for exemple-cleaning and cosmetic products)
REFUSE/RETHINK	refuse a bag for easy-to-carry purchases
	refuse to use single-use plastic, choose a reusable or recyclable product instead
	use water bottles and food container from other material: glass, metal, or plastic with repeated use
	refuse to use cosmetic products with microbeads
	refuse to consume tea packaged in teabags
RETURN	deposit-return system ("DRS")
	consumers return packaging at a drop-off point
RECYCLE	encourage Good Recycling Habits at Home
	sort household waste after use
	uses recyclable bioplastic objects
	plastic waste must be clean, empty and dry
Awareness and education of the population	awareness campaigns to raise awareness among locals about the importance of selective waste collection
	distribution of instructions on selective collection to locals
	making communication channels for the collection centers and the schedule
	establishing sanctions for non-compliance with the regulations related to selective collection, applicable to both sanitation companies and citizens

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Ch. 3 Assessment of water pollution, monitoring methods and best management practices in Armenia

Luiza Gevorgyan and Andranik Ghulijanyan

3. 1 Introduction

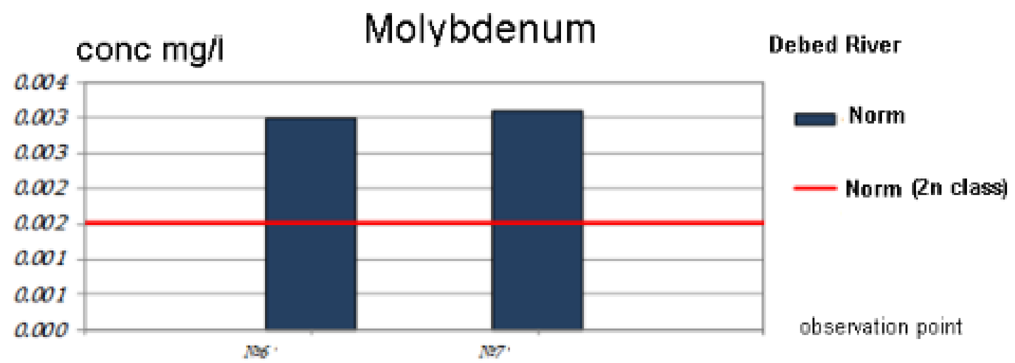
The water crisis can alternatively be called a governance crisis. Thus, the demand for good water governance to ensure effective water resources management and to attain specific water goals is growing [6]. The EU Water Framework Directive (WFD) adopted in 2000 by the European Parliament and the Council of Europe became an important 27 70 piece of water legislation aiming at improved water quality throughout the Europe. The Directive and its Guidance Documents provide the basis and methodology for specific actions targeted at protection, enhancement and prevention of any further degradation of aquatic ecosystems.

During the past decade Armenia has made a significant progress aimed at the improvement of water management system by establishing institutional and legislative framework. Water reforms in Armenia are targeted at harmonization with the European Union (EU) water legislation and application of the EU Water Framework Directive (WFD) approaches in particular. The Commission sees the Directive as a framework that would establish a common ground for the countries to ensure sustainable use of water resources and improve the status of aquatic ecosystems. To achieve this ambitious objective River Basin Management Plans (RBMP) will be developed and implemented for each river basin and updated every six years [1].

One of the most significant elements of the EU WFD is the adoption of a river basin as the management unit which reflects the natural situation of the ecosystem. River basin plan is the key tool for implementation of the new management approach. It requires complete information on the real situation in the river basin, including water quality status and any existing pressures that might affect it. Significant efforts on piloting and testing the EU WFD approaches in Armenia have been made by the EU funded project “Trans-boundary River Management for the Kura River Basin - Armenia, Georgia and Azerbaijan Phase II” (2008-2011) followed by Phase III (2012). New EU WFD compliant monitoring program for Armenia has been proposed, and tested during the 2012 by the Environmental Impact Monitoring Centre (EIMC), the state authorized body in charge of surface water quality monitoring in Armenia [5].

3.2 Assessment of the water quality of River basins

The River Basin Management Plan developed for the River Basins of Armenia, analyses water quality data collected in the sampling sites according to the new EU compliant monitoring program and attempts to identify how will the classification of water bodies in any River Basin will be modified based on the new monitoring results. The role of biological monitoring data for implementation of the WFD is explicit, since it provides essential information for assessing ecological status of a water body and defining its quality class (high, good, moderate, poor and bad) by using an ecosystem approach and assessing the ecosystem health and functions. The importance of biological data is explained by the ability of aquatic organisms (especially, the macroinvertebrates, due to their ecology and life span) to respond to impacts and changes occurring in the system over time. For example, abrupt pollution discharge would be difficult to reveal by chemical monitoring, while local biodiversity may be affected for a longer period of time [1].Water quality monitoring data of several rivers in the Northern Basin Management Area[1]



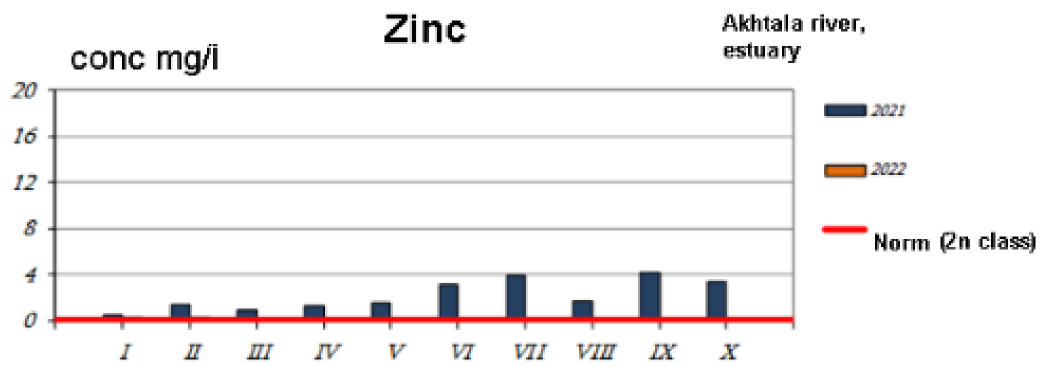


Figure 1 Estimation of Molybdenum and Zinc at the Debed and Akhtala river, respectively.

[1] http://armmonitoring.am/page/17

However, there is no biological monitoring in place in Armenia. Some fragmented studies in the rivers are conducted by scientific institutes depending on the research interests and funds available for a particular study. An important step towards the introduction of the EU WFD in Armenia has been made by adoption of Resolution No. 75-N of January 27, 2011 "On Definition of Water Quality Norms for each Water Basin Management Area, Taking into Consideration Local Specifics", which contains the WFD Priority Substances and other pollutants. Five water quality classes (I-V, corresponding to "high", "good", "moderate", "poor" and "bad") for a number of physico-chemical parameters have been specified for each of the six basin management districts in Armenia.

3.3 RBMP structure and functionality

Based on the concepts and approach of the EU WFD and the content of Armenia's Water Code, a River Basin Management Planning Guideline for the first time in Armenia has been developed on the example of Meghriget River Basin in 2008 [23], and Aghstev River Basin Management plan in 2009 [20].

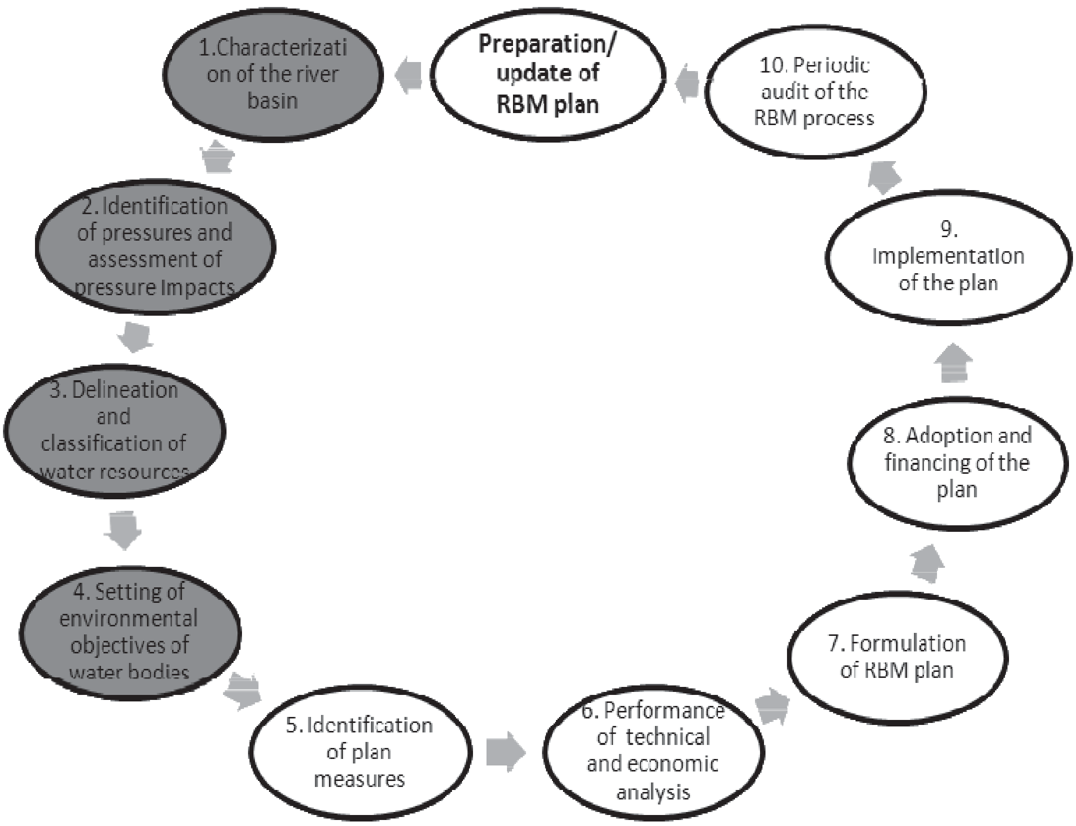


Figure 2. River Basin Management Planning Guideline for Armenia.

The components of RBM plan are:
The first four steps consist of the scientific-methodological basis of the Integrated River Basin Management planning and they are examined by the authors in this paper.

3.4 Characterization of the river basin

Characterization is a review of the physical, biological, geographic, social and economic condition and water use situation in the river basin. It provides background information for next steps of planning.

The physical-geographic-biological characterization needs to start with identification of the river basin of interest, and a description of its location, hydrography and topography, including appropriate maps. The following items are included:

- General description of location, defined river basin by exact downstream point of discharge, and names of its major upstream tributaries,
- Location map of river basin within Armenia,
- General map of the river basin including: labeled rivers, lakes and sub-basin stream names; major towns: principal (national) highways; borders of administrative units (marzes), and national border,
- Table of hydrographic data for the river basin, including for the entire basin, and each major tributary (more than 10% of basin area): watershed area, maximum elevation, minimum elevation, length of channel, gradient, river network density ,
- Additional sample hydromorphic data on the main river channel of the basin should be included, for example depth, width, width/depth ratio, sinuosity (total length/straight line distance) and type of channel form (braided, meandering or straight), modifications that take place in-stream,
- Any natural lakes should be characterized as to area, maximum depth, average depth, and location (coordinates) in a table,
- Topographic map of the entire basin, with a minimum of 40-meter contour intervals (depending on steepness of basin).

Brief descriptions of *geology*, *hydrogeology* and *soils* of the river basin, including:

1. Geomorphologic map of basin
2. Geologic map of basin (rock types) with particular attention to limestone

(calcium carbonate or "karstic") types due to their hydrologic properties,

3. Soil maps for the basin should be provided, but soils should be aggregated into categories so that only 7-10 total types are shown (otherwise the maps become too difficult to interpret),
4. Map of major known aquifers, if it exists,
5. Hydrogeological map of the basin with major aquifers springs and wells.

The climate, water quality of the river basin, including:

- Monthly and annual precipitation, temperature statistic data for stations within the basin
- Isohyet map of estimated average annual precipitation by elevation for basin,
- A summary table and short description of long-term water quality monitoring stations in the basin, and short description of water quality status for natural surface waters are useful.
- Water quality analyses for aquifers (well data) and springs/sources should be summarized in tables, with each well site separate, if any data exists.

The biological data includes information on the ecological zones, vegetation (especially wetlands), and the principal fauna of the region, with particular emphasis on the aquatic fauna.

Socio-economic characterization includes a description of the pressures on water resources, including population, agricultural and industrial development, economic activity and infrastructure. These factors are the key drivers of how water is used in the river basin. Later in the river basin plan this information will be used to inform the pressures and impacts analysis.
The social data includes information about the population, its demographics, historical land use and water use, health and education status, and general infrastructure of the river basin. These data had been extracted from Census 2001 and now can be updated by Census 2011 data. The economic data includes data on employment, income, land and water use in agriculture.

Socio-economic characterization includes the following items:

- Map of social infrastructure, including: roads, railroads, water supply systems, power generation facilities and distribution networks (irrigation infrastructure will be mapped in a distinct section to be described as "water use characterization.")

- Map of all inhabited areas of the river basin (villages, towns and cities expressed in relative population size) and census Database for creating derivative table information and maps of population density, age distribution and life expectancy, immigration and emigration rates, literacy rates, and educational level of population

3.5 Analyses for Economic Characterization of Basin

The economic characterization should focus on the employment, income and water resource impacts of distinct sectors of the economy in the river basin. The following items are included for the river basin characterization: a) map of crops in hectares, large and medium-size dairy production facilities, poultry and pig farms, major forestry and roads crossing those, location of the major current and historical mining sites; b) tables on the employment and income statistics by sector, tables explaining area in hectares of each major crop within the basin, livestock census. The water use characterization combined with hydrology, is the main factor affecting water quantity and water quality characteristics of the river basin. Water use data includes both water abstraction and wastewater discharges in a basin, as well as water transportation from one basin to another. The principal sectors of water use are the following: the municipal and domestic, irrigation and agricultural, large industrial, recreational, fisheries, hydropower.

Water Balance is considered as a basic quantitative characteristic of River basin and calculated as a relation of water inflow, outflow and accumulation (change of storage) in any river basin or water object in a given period (year, month, decade and other). The method is based on the difference of the volume of water inflow and the volume of water outflow in any watershed area and should be equal to the change in water quantity (increase or decrease in volume stored) within the given watershed area. The water balance quantitatively represents water circulation in nature, particularly the critical relationship between precipitation, evaporation and runoff [7], [8], [9]. One of the main advantages of proposed method is that it also allows calculation of water balance for ungauged river basin. In addition, a special computer program has been developed for calculation of water balance.

Water economic balance is the comparison of water resources and calculated water demand in the region for definition of the extent of water resources satisfying the demand, as well as the surplus or deficit of water resources due to spatial and temporal variations. Particularly, water economic balance provides a possibility to issue water use permits based on reliable information, as well as to define realistic objectives for river basin planning. Hence, based on the objectives set, it will be possible to identify corresponding measures for proper maintenance and management of water resources in the given river basin.

Water balance for aquifers is calculated based on assessment of inflow and outflow of waters to and from an aquifer. As a result, underground water resources are assessed, and possibilities of obtaining sustainable water yield from those structures are described. The European Union Water Framework Directive provides guidance on integrated water resource planning, including the integration of surface water and ground water resources planning. The basic principle is that aquifers must be managed for good chemical status (no pollution), and for a balance between recharge and withdrawal, so that the long-term water yield is sustainable. Assessment of water balance for aquifers in a given river basin provides a possibility to obtain necessary information on potential underground water resources in the river basin, and based on it, to estimate long-term sustainable water yield to support economic development, as well as implement optimal distribution of underground waters. Once the status of an aquifer's water balance is assessed, then reasonable environmental objectives for that aquifer can be developed.

Maximum discharge is associated with flooding and mudflows. Hence the calculation of maximum discharges for different probabilities of occurrences is important for determination of frequency of the above mentioned threats [19]. Calculation of maximum discharges is an important part of planning, particularly land use, transportation and urban planning and planning of agricultural investments and hydraulic infrastructure in general [13].

3.6 Identification of pressures and Assessment of Pressure Impacts

3.6.1 Identification of Pressures

The analysis of pressures and impacts is one of the procedures of basin planning as required by Article 5 of the Water Framework Directive (WFD) [12]. According to the WFD requirements, in order to identify pressures in the river basin, data on types and extents of significant human pressures occurring within the basin is gathered and analyzed. The identification of the pressures is implemented in accordance to the list included in Section 4.2 of WFD IMPRESS guideline [10]. Thus, the pressures are categorized by the following types in Table 1:

Table 1. The types of pressures in a river basin.

1. Water abstraction for household purposes	8. Fisheries
2. Water abstraction for irrigation purposes	9. Crop production including use of pesticides/fertilizers
3. Water abstraction for industrial purposes	10. Livestock breeding
4. Urban waste waters (including use of sewage water wells)	11. Overgrazing
5. Industrial waste waters from food processing industries	12. Timber production
6. Other industrial and mining wastewaters	13. Road traffic
7. Hydro power plants	14. Solid wastes

The objective is from the above-mentioned pressures to select and describe those pressures which have significant impact on separate parts of the river basin.

3.6.2 Assessment of Pressure Impacts

The objective of the pressure analysis is to identify the most important, significant pressures, which by their own or together with other pressures have such impact that deteriorates water quality or quantity status. The analyses are conducted according to the EU WFD IMPRESS Guidelines [7], the results of which are used for identification of water bodies at risk.

The concentration of pollutants (C) in point source of pressure in the river is calculated by the following formula:

$$C = \frac{q_0 c_0 + q_1 c_1}{q_0 + q_1}, \text{ where}$$

q_0 is the river discharge before the pressure point,

c_0 is the concentration of pollutant in the river water at the same point

q_1 is the volume of wastewater discharged into the pressure point, and c_1 is the concentration of pollutant in the wastewater.

Using the same logic the concentration of pollutants due to discharge of wastewater into the river can be calculated. These concentrations are treated as an assessment of point source pressure:

$$C = \frac{q_1 c_1}{q_0 + q_1}.$$

In order to assess the impact of pressures the final result of calculations, C , is compared to the marginal values of Danube River classification scheme [22].

In order to assess the urban wastewater discharge pressure an approach is using, which takes into consideration the number of population. This method is particularly useful for calculated the BOD5 index. According to EU VI Framework Program during the summer low-flow period 1 mg/l of BOD5 is considered as marginal value, above which the pressure is considered significant. Using the know norm that the quantity of BOD5 in discharged wastewater is 60 g/day* N, where N is the number of inhabitants, the concentration of BOD5 is calculated in the river's water at discharge point using the following formula:

$$C = ((60g/day * N * 1000)\ /(24 * 60 * 60))mg/l\ .$$

3.6.3 Classification of water bodies including delineation of water bodies

The primary purpose of classification is to assign each surface water and ground water body (aquifer) to a category or type which has its own set of distinct, and ecologically appropriate environmental objectives. Water resources cannot have the same natural and anthropogenic conditions (thus the same quantity and quality indicators) throughout their entire length (rivers), volume (lakes) or area (groundwater). That is why the application of the same standards for planning and management on the entire water resources will not be efficient. It is necessary to delineate water resources into discrete sections, or "water bodies" so that each section, within its length, volume or area has similar natural and anthropogenic conditions, and as a result can be represented by a single set of water quantity and quality indicators [14], [17].

The European Water Framework directive recognizes that certain types of man-made waters, known as highly-modified water bodies (canals, some reservoirs) cannot be expected to reach the same high environmental objectives as natural waters. Armenia's approach reflects the European approach in this and several other aspects. However, Armenia's Water Code also requires that water bodies be “classified” or described, according to a large set of criteria. This descriptive classification is complementary and parallel to the system described here.

EU proposes the following groups of characterization indicators: physical and biological, socio-economic, actual water use in the basin, water balance, environmental factors affecting the water and water use patterns. Below the main factors are listed, the existence of which causes quantitative and qualitative changes in water resources. That is why they might serve as criteria for delineation.

1. Absolute altitude of the territory above the sea level, which defines changes in water ecology (warm and cold waters),
2. River basin relief (field, plain, mountainous, valley),
3. The main confluences (junctions) of rivers,
4. Large settlements, industrial enterprises, or intensive agricultural zones,
5. Hydro-morphological criteria, which include the extent of modification of natural river bed or lake bed.

The EU WFD criteria for classification of water bodies in physical- geographic conditions of Armenia are used as follows. Category of water resources can be defined using the systems “A” of continental ecological regions. Being a method for characterization of basins and surface water resources, these systems allow delineation of water resources into discrete bodies based on the values of characteristics, as well as the following classification of water resources and their discrete bodies [22].

Rivers: According to the system “A” it is suggested to apply the absolute altitude of rivers while being characterized as follows: high > 800m, average 200-800m, low < 200m. In Armenia there are no rivers below 200 m. Thus according to the EU WED absolute altitude scale, the Armenian rivers will be characterized only as being average and high altitude.

The next value, according to which rivers are classified, refers to the size of the river basin. According to the WFD, the river basins are divided according to these classes: small (10-100 km^2), average (100-1000 km^2), large (1000-10000 km^2), very large (>10.000 km^2) river basins. It is suggested that this characteristic of river basins can be used to distinguish Local, National and International rivers (per definitions of the National Water Program), such that rivers with basins of less than 100 km^2 are coded as “Local,” rivers of 100-1000 km^2 are coded as “National,” and rivers of greater than 1000 km^2 (or river which form international borders) are classified as “International.”

In this case the number of classes for the territory of Armenia is reduced, since there are no river basins with an area of more than 10000 km^2. Thus, in this case the rivers or their different sections are divided into three classes. A geology characteristic takes into consideration the type of rocks which make up the majority of the river basin. The characteristic is contingent upon the origin and composition of the rocks. The EU WFD proposes the following characteristics for geology: calcareous, siliceous and organic rocks. The geology of the Republic of Armenia is represented only by two types of rocks: calcareous and siliceous. The geology factor explains several properties of the river basin. For example, siliceous rocks are weakly dissolvable, and except cracked rocks, they have low water- bearing properties, whereas calcareous rocks are usually porous and easily dissolvable.

Lakes: According to the EU WFD Lakes are divided to the following types: high (with altitude more than 800 m), average (200 – 800 m) and low (less than 200m). Thus, all the lakes in Armenia are classified as high according to EU WFD characterization. The average depth is a characteristic for classifying lake ecosystems. It is divided into the following interval: up to 3m, 3-15m, >15m. It is obvious that these average depths will correspond to ecosystems with different property types. Moreover, various segments of the same water resource (lake) might have significantly different depths, based on which the separate segments of the lake will be delineated (for example large and small Sevan).

According to the WFD, characterization and delineation of lakes by surface area is done using the following intervals: 0,5-1 km^2, 1-10 km^2, 10-100 km^2, 100 km^2 and more. The geology characteristics take into consideration the origin of mountainous rocks comprising the watershed of the lake and their composition, which is the same as for the rivers. Heavily-modified and Artificial Water Bodies such as reservoirs, drainage canals and irrigation structures, straightened, channelized, and reinforced, artificial ponds constructed for agricultural or other economic purposes urban river channels are delineated as separate water bodies.

Groundwater resources: Armenia's ground waters are delineated and mapped as 43 distinct, significant underground water bodies. They are located in different hydrogeological conditions, and thus have difference from each other in numerous properties. As classification criteria, the main hydro-geological conditions are selected, that form the main properties of underground water bearing bodies: these are geological conditions, structure, lithology, location depth of water bodies, which has an important role in forming resources for groundwater [10], [20].

3.6.4 Setting of Environmental Objectives of Water Bodies

Environmental objectives are the desired conditions of water quality and water quantity which expected to be achieved during a river basin plan valid period for each distinct water body [12]. Modern river basin plans, such as recommended by the EU WFD, require water bodies to meet biological, chemical/physical and hydrologic objectives, which in combination, reflect a desired "good water status". Armenia has sufficient monitoring data on chemical/physical and hydrologic and limited data available on biological conditions of water resources. Evaluation and Setting of Environmental Objectives includes several vital parts of the river basin planning process. Evaluation of status is the process by which Armenian standards are compared to the actual water quality and flow characteristics of a surface water body to determine whether it meets the requirements of human health and support for aquatic life. The environmental objectives are set in order to measure the progress of improvement in water resources during a river basin planning period, usually a number of years. Environmental objectives are quantitative and can be measured by monitoring. Environmental objectives for surface waters include physical and chemical water quality (qualitative criterion), and maintenance of minimum environmental flows (quantitative criterion). For groundwater, the key objectives are to maintain a balance of recharge and discharge from the aquifers, while remaining free of toxic contaminants.

3.6.5 Setting Environmental Flow standards

Environmental flow is the minimum level of river flows, required to maintain the proper functions of river network ecosystem. Assessment of environmental flow requires taking into consideration several factors, and is a complex issue. That is why as a first step it is necessary to consider the "environmental flow" to be the minimum quantity of water for which the river system has functioned under natural conditions. Moreover, the value of environmental flow cannot be considered constant throughout the year. Environmental flow should be defined for each month separately, to take into account that natural flows vary throughout the year, and aquatic species often require this seasonal variation in flow to implement their life cycle.

The study of many rivers of the republic showed that the natural flow reaches its minimum value in January-February, that is, until beginning of thaw next year. This can be explained by the fact that the mountainous rivers are fed mainly from spring thaw waters. The values of summer minimum natural flow of those rivers are mainly on average bigger by 10%-20% than winter minimal flows.

At the same time, based on the fact that in winter the economic impact on the river flow regime is very minimal due to irrigation termination, and the difficulty of accurate assessment of daily values of this impacts at the water intake points, it has been adopted that during January-February the flow through the river is very close to the natural flow.

Taking into consideration the hydrological regime of the rivers of the Republic of Armenia, the geographical area in which it is located, its economic use and the extent, water qualitative and quantitative structure and other factors, the RA Government in 2011 established a new approach of environmental flow determination. According to this approach, for the assessment of environmental flow the average value of the minimal flow of 10 consecutive days during the winter period is used. After that monthly values of environmental flow are calculated by the inter-annual distribution of multi-year minimum monthly flows.

3.6.6 Water Quality Classification

The localized version of Water Quality Canadian Index (WQCI) was used as a criteria for surface water quality for the Meghriget basin, based on 31 parameters and selected 9 parameters, which characterize the agricultural pollution. However, given the overall objectives of identification of anthropogenic pressures on water resources in Aghstev River basin, another principle was selected for assessment of water quality and classification of water bodies according to quality. The principle is based on chemical monitoring of data and uses the background/reference concentration of heavy metals, instead of applying the principles of maximum allowable concentrations. Water quality classes are selected according to the definition of EU WFD and for that purpose use the Danube River classification scheme and the technical standards of Slovakia (for phenols and oil hydro-carbonates) [18], [21], [22].

3.7 Best management practice

Integrated Water Resources Management (IWRM) is “a process that promotes coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” In the broadest sense, good practices are a set of guidelines, ethics or ideas that represent the most efficient or prudent course of action to achieve some goals. In the IWRM context, good practices are a set of activities, practices and tools designed to minimize negative effects upon the environment and water resources, promote efficient use of resources, improve safety for consumers and foster economic viability. The definition of what is good varies according to context and sector (IFSA, 2005).

Thus, good IWRM practices are recommended methods, structures and practices designed to prevent or reduce water pollution, reduce resource wastage, promote efficient resource use, combat environment deterioration, and enhance sustainability and social equity, while maintaining economic efficiency and well-being [24]. The IWRM diagnostics procedure for identifying good practices can be taken from the procedure of the Food and Agriculture Organization of the United Nations[2] , which includes the following.

Environmentally, economically and socially sustainable: a "good practice" meets current needs, in particular the essential needs of the world's poorest, without compromising the ability to address future needs. In a situation of competition for scarce water resources, not recognizing the value of water can lead to water being allocated to low-value uses and does not provide incentives to treat water as a limited resource. That is, water users should pay for water services for domestic drinking water, agricultural water use and all other uses. **Gender-sensitive:** a description of the practice showing how actors (men and women) involved in the process were able to improve their livelihoods. Good practices should consider women's participation and empowerment. **Technically feasible:** the ability to learn and implement good practices with good scientific backing. Good IWRM practices will base management decisions on scientific findings.

Inherently participatory: addresses inclusiveness and gender dimensions, bridging the gap in decision-making between decision makers and water users/community members, through efforts to raise community awareness in schools, youth, etc., and capacity development for water management. Participatory approaches are essential as they support a joint sense of ownership of decisions and actions. The lowest appropriate management level needs to be as close to the action as possible. Good IWRM practices consider management at the community level through community organizations.

Scale: the scale at which the management happens defines the boundary conditions, which could range from a whole river basin/catchment or micro-catchment at village or locality levels. Good IWRM practices consider hydrological boundaries as the scale for management interventions. **Vertical and horizontal coordination:** assumes effective communication among water

[2] https://www.fao.org/capacity-development/en/

users and related ministries and public agencies, etc., including upstream-downstream issues, domestic resources within the same State versus trans-State or transboundary management and federal- versus State-level dynamics.

Integration: an important constituent of the concept of IWRM and includes integration in all contexts (managerial, administrative, technological, behavioural and, above all, political). Therefore, in this study, integration among two or more sectors, integration of the resources and also in using the same water source (multipurpose dams), along with allocation and a licensing system, are considered good practices.

Replicable and adaptable: a good practice should have the potential for replication and should therefore be adaptable to similar objectives in varying situations. Reducing disaster/crisis risks: a good practice contributes to disaster/crisis risk reduction/ adaptation for resilience.

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Ch. 4 Best Management Practices Review
Literature review on erosion prevention in Moldova

Ecaterina Kuharuk and Olga Crivova

4.1 Introduction

The Republic of Moldova is located in the southwestern part of the Eastern European Plain, mainly between the Dniester and Prut rivers. Extreme points: in the north - Naslavcea Village, Ocnita region (48° 29' 31"N, 27° 35' 28"E), in the south - Giurgiulesti Village, Cahul region (45° 28' 59"N, 28° 12' 53"E), in the west - Kriva Village, Briceni region (48° 16' 29"N, 26° 37' 05"E), in the east - Palanca Village, Stefan Voda region (46° 24' 49"N, 30° 09' 55"E). The territory of the country is elongated in the meridional direction, its area is 33.8 thousand km2. From north to south it has a length of 350 km, from west to east - 150 km. In the north, east and south, the country borders with Ukraine, and in the west - with Romania.

Relief

Geographically, the territory of Moldova is located on the East European Plain. Its surface is strongly dissected by the valleys of the Dniester, Prut and their tributaries, and in general it is hilly, sloping from northwest to southeast, the height above sea level varies from 300 to 150 m. The exception is the central part of the country, where interfluves reach 300-400 m above sea level. Seven orographic units are distinguished on the territory of the Republic of Moldova: Northern Moldavian Steppes and Plains, plains and steppe hills of Northern Moldova, The forest-steppe region of the Podolic Plateau, forest region of Bâcului Plateau, Region of the Plains and Forest-Steppe Plains of Southern Moldova, Bugeac steppe plain region, the region of the Dniester steppe river plain [1]. Among the exogenous processes of formation and evolution of the relief observed on the territory of the Republic of Moldova, the most important are erosion, landslides, karst collapses, subsidence. Erosion and landslide processes are the most widespread.

Water resources

Moldova has limited groundwater resources. General developed reserves amount to 1.5 cubic km. On average, 100 l/day falls on one inhabitant, in Chisinau - 350 l/day, while the necessary amount, according to UN standards, is 1000 l/day. The southern regions are the poorest in water resources, where in some places underground water resources are equal to just 17-18 l/day per person. Most of the developed water reserves fall on the valley of Dniester River. In the Prut River valley and in the south of the country there is a shortage of groundwater. In terms of chemical composition and quality, only a third of groundwater resources meet the basic requirements of the drinking water standard. About 20% of the total reserves can only be used for technical water supply due to the increased content of fluorine, nitrates and sulfates, excessive mineralization, high content of nitrates and sulfates, and bacteriological contamination.

Land resources

According to the cadastre, the total area of the country is 3384.7 thousand hectares. As of January 1, 2021, the total area of agricultural land amounted to 2129.5 thousand hectares.[2] The area of irrigated land is 217.94 thousand hectares. Compared to the situation as of January 1, 2020, there is a decrease in the reserve fund by 41.24 thousand hectares as a result of the exclusion of land occupied by buildings and extensions of former agricultural units. Lands owned by the state make up 783.87 thousand ha, administrative-territorial units - almost 700 thousand ha, and lands in private ownership - more than 1901.5 thousand ha.

4.2 Soils

One of the main natural resources of Moldova is fertile soils. The soils of the country are very diverse, which is explained by the great heterogeneity of natural conditions, under the influence of which the development of the soil-forming process proceeds. This was also pointed out by V.V. Dokuchaev (1900), A.I. Nabokikh (1910-1912), N.A. Dimo (1958). Soil is a natural body, which is a complex mixture of mineral, organic and organo-mineral substances. The soil is fertile, which allows it to participate in the reproduction of plant biomass. In the soil, living and non-living things exist in an inseparable connection. Therefore, the soil is considered a special natural formation - bio-inert. The soil is a source of food, providing up to 97% of food resources for the world's population [3, p.21]. According to the landscape, many soil scientists divide the Republic of Moldova into three parts - the northern forest-steppe, the central forest and the southern steppe, each of which has a rather specific soil cover. Various chernozems (Black Soil) predominate in this motley and diverse soil cover. They are distributed in all steppe and forest-steppe regions of the republic and make up about 2.5 million hectares, or 80% of its territory.

The Moldavian chernozems are very thick; contain humus not only in the upper arable layer, but also in deeper layers. These soils are dark, almost black when wet, have a granular structure and therefore absorb precipitation well. Chernozems are very different. The best of them are called typical. They occupy the northern part of Moldova - the Northern Moldavian Plateau, sections of the Northern Moldavian Plain, the Balti Plain, the lowered outskirts of the Transnistrian Upland, most of the left bank of the Dniester. The best varieties of winter wheat, corn, sugar beet, tobacco, apple and pear are successfully grown on the chernozems of northern Moldova. Leached chernozems are close to typical chernozems in terms of properties and use. Their difference lies in the fact that the leached chernozems have a deeper layer with fame. This has a positive effect on the growth and development of fruit trees [4, p.40-61].

On the plains of the south of the Republic of Moldova, ordinary chernozems predominate. They are much lighter than typical chernozems. Almost all cultivated plants on ordinary chernozems give slightly reduced yields. Only sunflower and grapes are exceptions and grow well on these soils. In the southern regions there are carbonate chernozems. They are poorer than ordinary humus, less fertile, already in the arable layer of the soil contain a lot of lime, which causes an alkaline reaction of the soil, adversely affecting many plants. However, grapes, grain crops and sunflowers grow well on carbonate chernozems, although they give a slightly lower yield than on other chernozems. Chernozems in the Republic of Moldova are usually located no higher than 250-270m. Above the chernozems are forest soils.

The northern Moldavian plain, the Central Moldavian, Transnistrian and Tigheci plateaus in the most elevated parts are occupied by various forest soils. In general, their area in the republic is about 500 thousand hectares, of which 200 thousand hectares are occupied by forests and 300 thousand hectares by perennial plantations and arable land. In addition to forest soils and chernozems, on an area of about 250 thousand hectares, floodplain soils are widespread, formed in the floodplains of the Dniester and Prut and other rivers as a result of the deposition of fruit-bearing deposits. Floodplain soils contain a lot of humus and other nutrients, so these lands are good for intensive gardening and vegetable growing. Thus, chernozems, forest and floodplain soils complement each other favorably, create great differences in vegetation cover, and ensure the harmonious development of agricultural sectors.

The diversity of the soil cover of agricultural land in the Republic of Moldova (without the left bank of the Dniester) is shown in Table 1 [5, p.30-32]. A feature of the fund for agricultural purposes is the predominance in its structure (up to 82%) of chernozems of various types and subtypes. In terms of distribution area, it is followed by damp forest (more than 6.6%) and hydromorphic alluvial soils (occupying almost every 16th hectare). Land Fund of the Republic of Moldova as of January 1, 2016 amounted to 3384.6 thousand hectares and includes seven categories of land (Table 2):

- Agricultural land occupied 59.8% of the entire territory of the republic;
- lands of settlements - 9.3%;
- reserve fund - 13.3%;
- land for industry, transport, communications and other special purposes - 1.7%;

- lands of the forest fund and environmental purposes - 13.3%;
- lands of the water fund - 2.6%

Table 1. Distribution of soil types and subtypes on agricultural lands of the Republic of Moldova (without the left bank of the Dniester) (ha/%) [5].

Soil types	Cultivated lands (arable land plus perennial plantings), ha/%	Total, ha/%
Brown forest	404 / 0,03	478 / 0,03
Grey forest	108306 / 5,84	123711 / 6,68
Chernozems, total	1319050 / 71,3	1439867 / 77,83
Podzolized chernozems	44797 / 2,42	50899 / 2,75
Leached chernozems	294759 / 15,93	315076 / 17,03
Typical chernozems	148839 / 8,05	155304 / 8,40
Xerophytic forest chernozems	434 / 0,02	445 / 0,02
Ordinary chernozems	358823 / 19,40	369715 / 19,98
Carbonate chernozems	471398 / 25,49	548428 / 29,65
Compacted soils	6184 / 0,34	7698 / 0,42
Humus-carbonate	938 / 0,05	1533 / 0,08
Diluvial	511 / 0,03	666 / 0,04
Chernozem solonetz	582 / 0,03	1282 / 0,07
Reclaimed soils	197 / 0,01	993 / 0,05
Landslide redistributed soils	4795 / 0,26	18467 / 1,00
Semihydromorphic soils	43954 / 2,38	74311 / 4,02
Hydromorphic noninundated soils	14105 / 0,76	47046 / 2,54
Hydromorphic alluvial soils	65834 / 3 ,56	117271 / 6,34
Disturbed soils, non-soil formations	3857 / 0,21	18616 / 0,90
Total	***1568717/84,8***	***1849956/100***

Agricultural land as an entity includes areas used for various agricultural needs, a part of the reserve land and other funds, which in total amounted to 2521.6 thousand hectares or ¾ of the entire territory of the republic. Such a high proportion of land used for agricultural purposes, on the one hand, speaks of the high plowing of the country's land fund (arable land and perennial plantations - land in cultivation -

occupy 84% in the structure of agricultural land and 62.4% in the structure of the land fund) and about the lack of forests in the country, on the other hand.

The territory of the Republic of Moldova occupies one of the first places in the world by the percent of ploughed lands , and consequently, the last place in Europe by afforestation. For example, if the share of agricultural land in the structure of the land fund of the republic is 73.9%, then in Greece - 70.1, Romania - 62.0, Poland - 61.8, the Netherlands - 59.5, India - 60.9, Italy - 57.5, France - 55.8%.[6]

Table 2. Dynamics of the land fund of the Republic of Moldova for 1995 – 2015 [5].

Land types	1995	2005	2010	2015
Total land area	3385,3	3384,6	3384,6	3384,6
Agricultural lands	2032,6	1951,8	2007,6	2026,5
Lands of settlements	441,7	308,6	311,6	314,8
Reserve land	462,5	553,8	469,9	449,0
Industrial, transport, communications and other special purposes lands	58,4	58,8	58,7	58,7
Lands of the forest fund and those intended for nature protection purposes	344,1	428,5	450,0	450,5
Water fund lands	46,0	83,4	86,8	85,1

In 2015 the area of land covered with forest vegetation amounted to 339.4 thousand hectares. The territory of the country is afforested by 10.0%, which makes the republic one of the European countries with the lowest level of afforestation (the average value in Europe is 29%, in the world - 31%). The land resources of the regions are conditionally divided into two parts: one part (tillage land - arable land and perennial plantations) is actively used in agricultural production, the other is passively used (pastures, natural hayfields) (Fig. 1).

Table 3. Composition and structure of agricultural land in the Republic of Moldova (as of January 1 of the respective year) [5].

Land types	1990		2000		2010		2015		
	*10³ ha	%	*10³ ha	%	*10³ ha	%	*10³ ha	%	% from 1990
Agricultural lands, total	2559,7	100	2550,3	100	2501,1	100	2 499,7	100	97,7
As part of agricultural land: arable land	1735,4	67,8	1813,8	71,1	1816,7	72,6	1817,4	72,7	104,8
perennial plantings: including orchards, vineyards	466,4 222,9 211,8	18,2 8,7 8,3	352,3 170,8 168,9	13,8 6,7 6,6	301,0 132,5 153,5	12,0 5,3 6,1	291,7 134,5 137,5	11 ,7 5,4 5,5	63,6 60,4 65,0
Waste lands and grasslands	-	-	7,8	0,3	29,1	1,2	42,0	1,7	-
hayfields	2,9	0,1	2,5	0,1	2,2	0,1	2,2	0,1	75,9
pastures	355,0	13,9	373,9	14,7	352,1	14,1	346,4	13,8	97,6

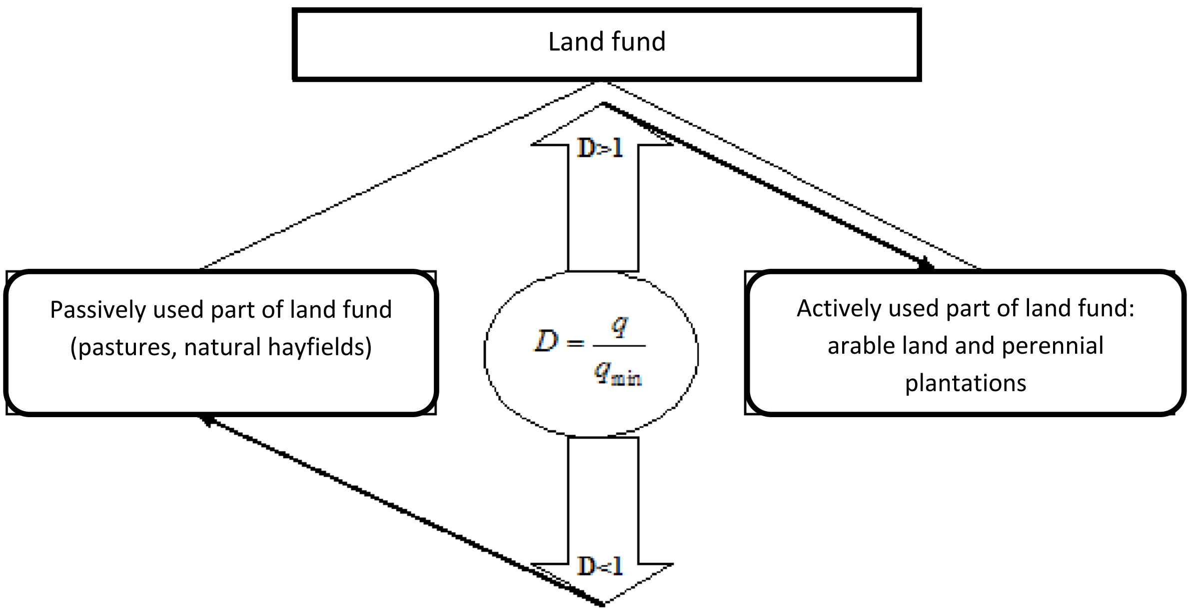

Figure 1. Land use scheme [7, c.16].

In reality, agricultural organizations, based on economic feasibility, decide for themselves which land plots to transfer from one part to another. At the same time, as an integral criterion for classifying a part of agricultural land as a passive part, it is advisable to use the indicator of the availability of land resources as the ratio of the actual yield to the critical (minimum) level:

$$D = \frac{q_{\phi}}{q_{\min}}$$

If the availability index is higher than one, then the land plot belongs to the active part.

4.3 Current status and possible trends

The Dniester is the largest river flowing into the Black Sea - the total length is 1362 km, within the borders of Moldova the length of the Dniester is 625 km. In the Dniester basin there is a wide range of soil cover, which is involved in agriculture. Landowners and farmers could thrive on such land: no country in Europe has 80% of chernozems in its soil cover [8]. However, the chernozem region, such as Moldova, is currently experiencing environmental, economic, social difficulties. One of the reasons is the improper use of the soil cover. In an agrarian country, there is no more valuable natural wealth than soil. The harvest of agricultural crops, the food security of the country depends on its condition [9].

To carry out measures to improve the soil cover, it is necessary to understand the current situation about the state of soils, the causes of their degradation and ways to solve problems that hinder sustainable development. At the same time, it should be understood that the complex of problems leading to soil degradation includes environmental, economic and social problems. This report examines in detail the causes of soil degradation, the factors affecting soil degradation, the qualitative state of soil resources (bonitet) of the left and right banks, and the processes that contribute to the manifestation and development of soil degradation.

Two aspects are important in the assessment of soil cover. First, despite erosion and partial salinization, soils in the Republic of Moldova are very fertile. The population could prosper on such land. Moldova is unique in this respect. The second important feature of the soils of Moldova is their diversity: there are more than 700 soil varieties on its territory [I.A. Figure 2. [10]. It also confirms a large percentage of the number of chernozems (70%). Thanks to such a variety of soils in Moldova, it is possible to grow grapes, fruits, tobacco, cereals and industrial crops. The variety of soils makes it possible to grow various varieties of apples, pears, plums, white and red grapes, both table varieties and for making all kinds of juices, wines and cognacs.

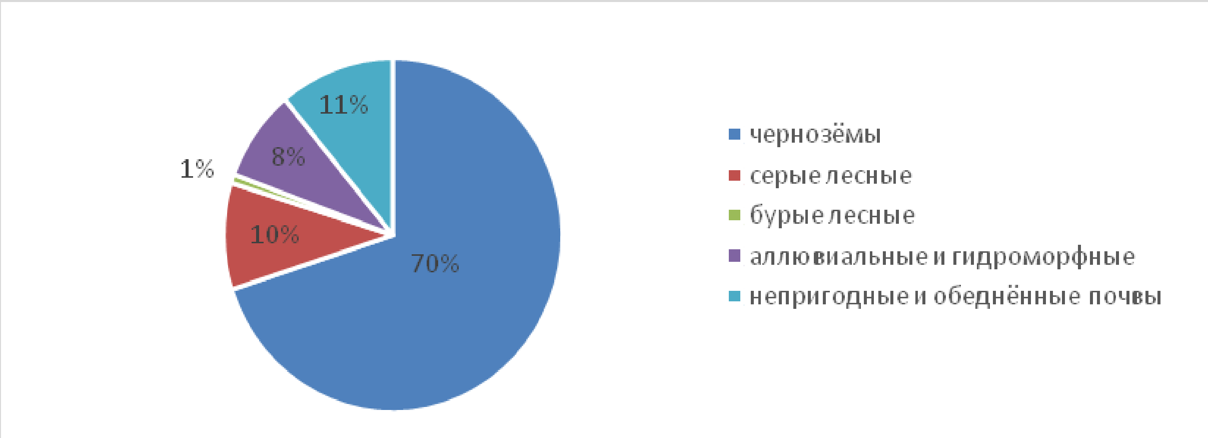

Figure 2. Distribution of the main types of soils of the land fund of Moldova,% (Cerbari, 2010).

4.3.1 Factors affecting soil degradation

The increase in eroded soils is associated with the relief of the Republic of Moldova. Moldova is strongly elongated from north to south - almost 350 kilometers. In the same direction, there is a general drop in the height of the terrain above sea level: the northern part of the territory is raised by an average of 210 meters, and the southern - by only 120 meters. Thus, the territory of Moldova is an undulating plain, in places elevated and hilly. In the center there is a hill with a maximum altitude of 429.5 meters (Mount Balanesti), and the average altitude of Moldova is 147 m. The altitude of the territory decreases from northwest to southeast. As a result, the northern and southern parts of Moldova differ in terms of average annual air temperature and annual precipitation (557 and 429 mm, respectively). The climate determines the vegetation, wildlife, and the entire landscape of the area, which leads to changes in the soil cover.

The complex fragmented relief contributes to erosion processes. Relief features need to be known during land management work to reduce soil erosion and recommendations for sustainable development. In Moldova, 80% of the territory is located on slopes steeper than 10. The soils of the slopes are subject to erosion processes. Slopes from 20 to 60 occupy 37%, and steeper 60 - 20% of the territory.

In Moldova, according to experimental data, the amount of eroded soil increases in proportion to the length of the slope. An increase in the slope length by 100 m leads to an increase in the amount of eroded soil by 1.5 times; doubling the length of the slope from 200 to 400 m increases this number by 4 times. It is necessary to use a system of anti-erosion measures in each specific case. The excessive nature of precipitations in the conditions of a fragmented relief contributes to the intensive development of soil erosion in this territory.

4.4 Soil erosion

The soil cover and its changes are not considered only for a short period of time. This may lead to an incorrect assessment of the situation and incorrect justification of measures and recommendations to improve the situation and management decisions for local authorities with public participation. During the period from 1965 to 2015, the areas of eroded soils increased by 227.7 thousand hectares, from 28.1% to 37.5% (or 1.1 times). The annual growth of eroded soils is 4.6 thousand hectares (or 0.22% per year). The dynamics of the areas of eroded soils on the left and right banks of these years is shown in Table 4.

Table 4. Eroded soils area dynamics (Land Cadastre of the Republic of Moldova. 1965, 1995, 2010, 2015).

Erosion level	1965		1995		2010		2015	
	*10^3 ha	%	*10^3 ha	%	*10^3 ha	%	*10^3 ha	%
Non-eroded	**1 517,4**	**71,9**	**1 287,5**	**61,0**	**1 234,6**	**58,3**	**1 460,9**	**62,5%**
Slightly eroded	302,4	14,3	485,3	23,0	504,0	23,9	504,7	21,6%
Moderately eroded	195,6	9,3	244,6	11,6	259,0	12,3	259,5	11,1%
Heavily eroded	96,2	4,5	94,2	4,4	114,0	5,4	114,1	4,9
Total eroded soils	**594,2**	**28,1**	**824,1**	**39,0**	**877,0**	**41,5**	878,4	**37,5%**
Total investigated lands	2 111,6	100	2 111,6	100	2 111,6	100	**2 339,3**	100

In total, eroded soils in Moldova in 1965 were 28.1%, and in 2015 eroded soils - 37.5%. Over a fifty-year period of time, such changes in the soil cover are unacceptable. What forecast for the next 50 years can be made for eroded soils if measures are not taken to improve degraded soils and preserve their fertility? It is alarming that slightly eroded soils currently account for more than % of the area of all agricultural land. Over time, slightly eroded soils pass into the category of moderately and heavily eroded, if anti-erosion measures are not observed, i.e. in the next decade, another 21.6% of slightly eroded soils will increase the number of moderately eroded soils, which means that the loss of agricultural products for our residents provides a path to poverty, and the soil cover degrades into barren soils. Therefore, it is easier to stop erosion at an early stage than to restore heavily eroded lands.

The figures for the increase in the share of all eroded soils (from 28.1% to 37.5%, over a fifty-year period) show how deeply the erosion processes of the soil cover develop on the territory of Moldova. As a result of the privatization of land, 26.0% of agricultural land, 14.6% of arable land, 12.8% of orchards and vineyards remained in state ownership. As you can see, for every 10 hectares of agricultural land, more than 7 hectares are privately owned. 1807 thousand hectares, or 85.7% of the most fertile lands of the republic - in the total, arable land and perennial plantations - are used in the private sector. On the other hand, 98.6% of the least productive lands - pastures - belong to the state. Reserves in full can be measured by the gap between the achieved level of resource use and the possible level, based on the existing production potential of the brigade, farm, enterprise as a whole. The production potential of land resources is understood as the maximum possible output of products in terms of quality and quantity under the conditions of the most efficient use of all available means of production and labor. Consequently, the total assessment of reserves for increasing production efficiency is characterized by the difference between the production potential and the achieved level of production.[6]

According to analytical data obtained by V.V. Dokuchaev, the soils of Moldova (more than 100 years ago) contained from 5 to 6% humus [4]. In subsequent years, the natural fertility of the soils of the republic was constantly decreasing. Now the humus content has reached the level of 3.1% on average for the entire plowed area. During the 20th century, only 50-60% of the original natural fertility of the country's soils remained. As you can see, the problem of preserving (reproducing) soil fertility remains one of the main problems in the agriculture today. Depending on the intended use, lands are subject to the influence of natural and anthropogenic factors to varying degrees. It should be noted that most of the loss of soils and their fertility is anthropogenic in nature, i.e. due to unreasonable human activity.

It is very important to understand the loss of soil cover due to erosion. Fig. 1 demonstrates the erosion (washout) of upper horizons in eroded soils. It shows the average soil profiles and the degree of their washout, which are established by soil scientists in the field studies. This is a generally accepted gradation of soil erosion, which is valid for many countries. In turn, in Fig. 3 the profiles of full-profile, slightly, moderately- and heavily-eroded soils are shown.

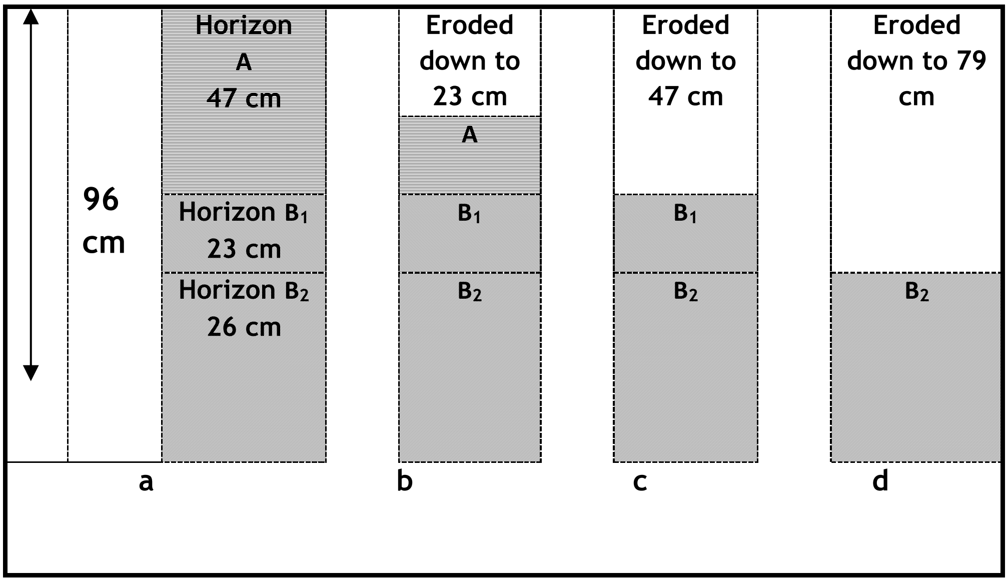

Figure 3. Degrees of erosion for the chernozems of all subtypes: a – full profile, \b – slightly eroded, c – moderately eroded, d – heavily eroded.

The available map of eroded soils, presented in Fig. 4, shows all degrees of erosion: slight, moderate and heavy erosion on the territory of Moldova. Figure 4 clearly shows the distribution of slightly eroded soils on the territory. If anti-erosion measures are not observed, they pass into the category of moderately eroded soils.

This, accordingly, also affects the decrease in crop yields, which are reflected in Table 5. This table shows the multiyear studies of corresponding decrease in the yield of the main agricultural crops, depending on the degree of soil erosion established for the territory of Moldova.

Yield loss on heavily eroded soils ranges from 65 to 90%, and on moderately eroded soils - from 40 to 70%. That is why it is so important for landowners to know the degree of soil erosion and soil quality they plan to work on, as yield reduction differs for different crops. For moderately eroded soils, there are measures to improve soil fertility that differ from other categories of eroded soils.

Table 5. Decreas of crop yields on soils with varying degrees of erosion, % [12].

AGRICULTURAL CROP	Degree of erosion	
	moderate	heavy
Sugar beet	60-70	85-90
Sunflower	50-60	70-80
Corn for grain	30-40	75-85
Winter wheat	40-50	65-70
Peas	30-40	40-50
Perennial herbs	10-15	25-40

The yield of crops is reduced by 10-20% on the slightly eroded soils, by 30-40% on the moderately eroded ones, by 50-60% or more on the heavily eroded. It is very important to understand the definition of soil erosion, since for the developed policies and recommendations they are given little attention by experts [13]. It can be noted that the yield loss on heavily eroded soils ranges from 65 to 90%, and on moderately eroded soils - from 40 to 70%. That is why it is so important for landowners to know the degree of soil erosion and soil quality they plan to work on, as yield reduction differs for different crops. For moderately eroded soils, there are measures to improve soil fertility that differ from other categories of eroded soils.

It is equally important to know that the content of humus, which determines soil fertility, is highest in the uppermost layers of soils and decreases sharply with depth. So, in a full-profile chernozem, on average, in a layer of 0-50 cm contains 3.52% of humus, in slightly eroded - a decrease in humus content is 20.5%, in moderately eroded - 42%, and in heavily eroded - 64%. Long-term studies of the agrochemical service of the Republic of Moldova established that for the period 1986-1990 the humus content was 3.1% on average for the entire plowed area. Over the past 100 years, the content of organic matter has decreased by 40-50% [14].

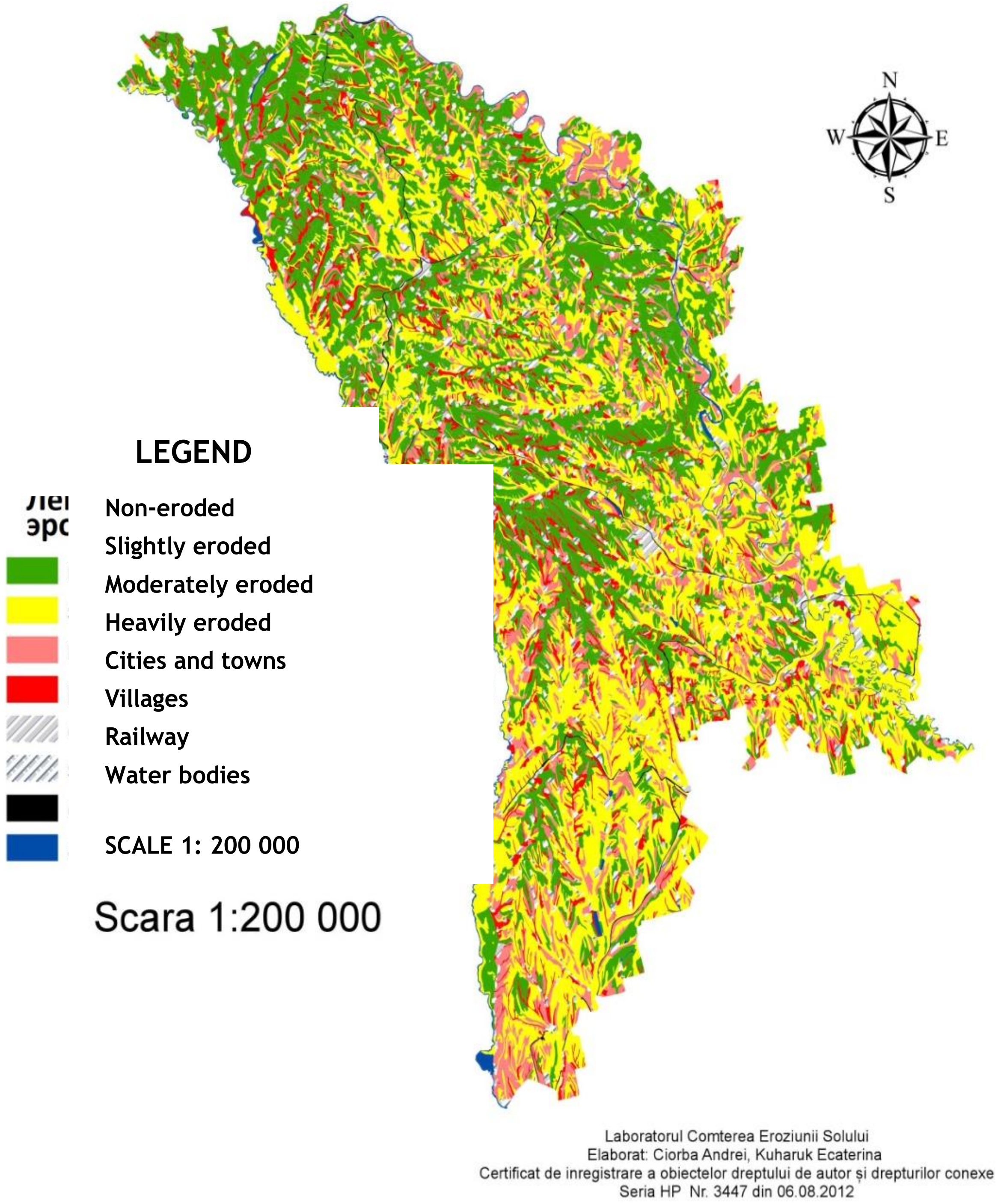

Figure 4. Map of eroded soils in the Republic of Moldova Source: Andrei Ciorba, Ecaterina Kuharuk, 2012 [11].

Losses of humus from agricultural land are related to many factors: crop rotations used, tillage, the amount of organic matter returned with organic fertilizers, the low proportion of perennial grasses in crop rotations, etc. Figure 5 presents the dynamics of humus content in the soils of Moldova over the past 110 years. After 100 years, the content of organic matter decreased by 40% and amounted to about 3.0%. According to forecasts, by 2025 the average content of humus will decrease to 2.7%. The decrease in the amount of organic matter in the soils of Moldova occurs as a result of humus mineralization and erosion processes. Due to these two processes, the amount of humus is reduced annually by 1000-1100 kg/ha [16].

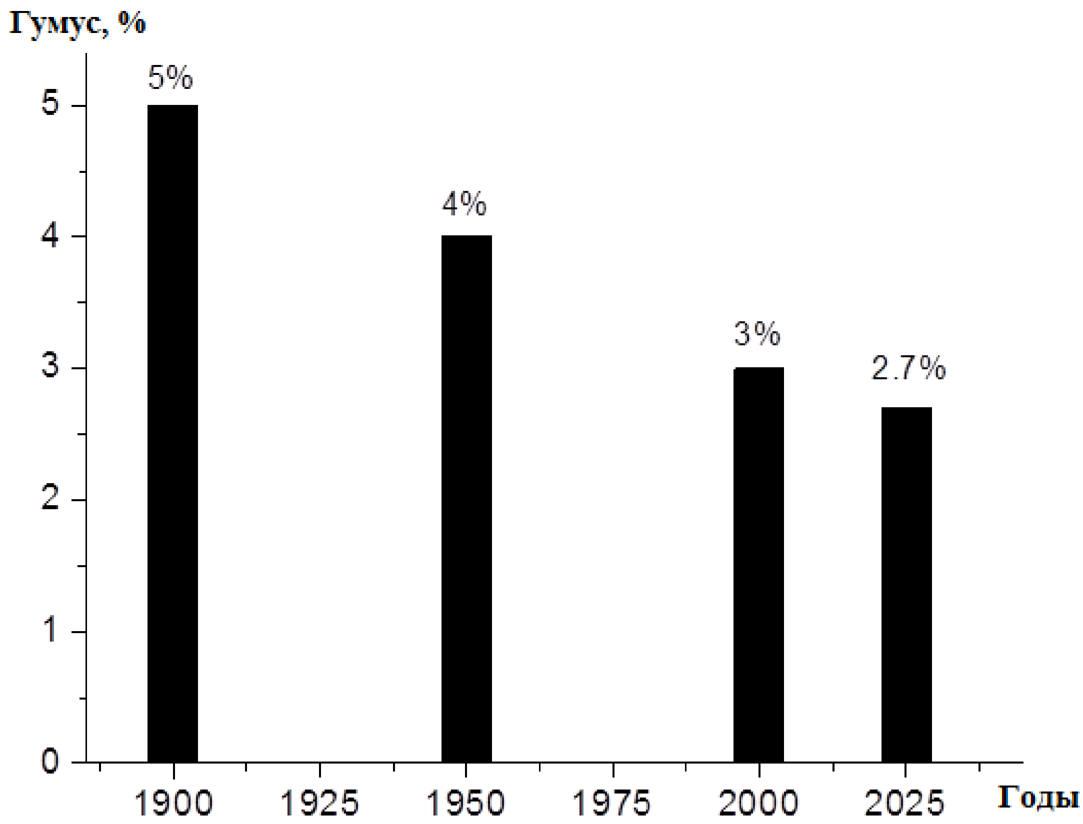

Figure 5. Humus content dynamics in the soils of Republic of Moldova [15].

What are the main reasons for the acceleration and spread of soil erosion in recent decades? The previously existing problems of the soil cover - the maximum economic development of the territory, the plowing of steep slopes, the immoderate poisoning of soil biota with pesticides, irregular grazing and others, were added by the almost complete cessation of the application of organic fertilizers, the plowing of fields along the slopes, excessive fragmentation of land into privatized areas, which objectively excludes the very possibility of using crop rotations, exporting the entire above-ground mass of plants from the fields (for livestock feed, for fuel), increasing the area under row crops (mainly sunflower and corn for grain), reducing the area under orchards and vineyards on the territory of 200,000 hectares [17] and their transfer to arable land, massive cutting down of forest belts and forests, rejection of even elementary measures to prevent or slow down the development of erosion, permanent cultivation of monoculture on the same fields x for many years, etc.

Soil erosion on the scale on which it is now observed is undoubtedly the result of human activity, which is why it was called anthropogenic erosion. It would be wrong, however, to attribute the cause of erosion solely to human activity. Soil erosion without human intervention has existed and exists at the present time. It is called geological erosion [18]. The concept of anthropogenic erosion is unreasonably identified with the concept of accelerated erosion, and the concept of geological erosion with the concept of normal erosion. And if anthropogenic erosion is (but not always) accelerated, then geological erosion is not necessarily normal. This is not always understood by workers in the managerial sphere of agricultural production, who put forward a proposal to stop soil erosion. Competence is needed in this matter of the management, who can consult with specialists in the field of erosion and soil protection. Widespread surface water erosion in the Dniester River basin is not as noticeable as ravine erosion, but very harmful. Under the influence of surface water erosion, not only soil fertility decreases, plants are damaged, and this leads to a loss of 10-70% of the crop [12], and the washed soil from the slopes ends up in the Dniester River. Silting of the river and increasing turbidity of the water in the river complicates the work of water supply systems and water transport. The amount of sediment transported by a river depends on the intensity of soil erosion in its basin.

The consequences of soil erosion, observed in the present and expected in the near future, if decisive measures are not taken, pose a real threat to the entire country. Erosion damage is expressed through the loss of fertile soil washed off the slopes. Every year, 26 million tons of fertile soil is lost from 1 ha of washed away soils from the entire territory, including the left bank of the Dniester (840 thousand ha) [19].
In modern conditions, as a result of the interaction of natural and anthropogenic factors, the processes of degradation of the soil cover are increasing. As a result, slightly eroded soils quickly turn into moderately eroded soils, which, in turn, evolve into heavily eroded ones. The process of soil degradation has become irreversible and is developing rapidly. Anti-erosion organization of the territory and observance of anti-erosion principles in agricultural economic activity are mandatory for 1,300 thousand hectares of arable land, 200 thousand hectares of vineyards and orchards, as well as 205 thousand hectares of pastures located on the slopes.

4.5. Government programs and legislation in the field of agriculture and soil protection

Regulations and policies are needed for the conservation and restoration of soil fertility of eroded soils and the development of organic agriculture, along with the programs that are aimed at their implementation.

4.5.1 Analysis of norms and programs to ensure soil fertility

Earth and soil are two different concepts. The land legislation defines land as an important part of the natural environment, characterized by space, relief, climate, soil cover, vegetation, subsoil, water, is the main means of production in agriculture and forestry, as well as the spatial basis for locating enterprises and organizations of all branches of the national economy. Soil is a narrower concept: soil is the surface layer of the earth, which has fertility. Landowners own land. The concept of a land plot is a part of the land surface that has established boundaries, area, location, legal status and other characteristics reflected in the Land Cadastre and state registration documents.

Land resources are regulated by normative acts, of which the main ones are:

- Constitution of the Republic of Moldova, 29.07.1994
- Land Code Republic of Moldova, 25.12.1991
- Environmental protection law, 16.06.1993
- Real Estate Cadastre Law, 25.02.1998
- Law on State Land Management, State Land Cadastre and Land Monitoring, 22.12.1992
- Law on Regulatory Land and the Procedure for the Purchase and Sale of Land, 25.07.1997
- Property Law, 22.01.2003.

This list is incomplete, because in addition to laws, there are a large number of normative acts - resolutions, instructions, regulations related to land. Programs for the improvement and protection of land are included in the function of the state land management service, including increasing soil fertility and the use of progressive environmentally friendly technologies. The principles of obligation in the land management system are that land owners, landowners and land users are obliged to comply with the requirements for maintaining and increasing land fertility, preventing soil erosion, and applying fertilizers in accordance with land management schemes and projects agreed with the state land management service.

[3] http://www.law-moldova.com/laws/rus/o_sobstvennosti_ru.txt

There are approved normative acts and programs on the left and right banks of the Dniester River aimed at monitoring soil resources, which include work on soil and agrochemical surveys, drawing up anti-erosion measures aimed at preserving and restoring the soil cover. The main standards and programs that are important for soil fertility are listed in Table 6 below.

Land management services provide soil monitoring as an integral part in determining the quality of land monitoring. The law of the Republic of Moldova: on state land management, state land cadastre and land monitoring [20] states that land monitoring is served by an information system that ensures the formation of a data bank on land resources and is an integral part of the country's information system. Land monitoring, which is carried out by cadastral services, includes the systematic conduct of soil, agrochemical and other studies necessary for the timely and correct determination of changes in the soil cover. These works are aimed at preserving and improving soil fertility.

The National Action Program to Combat Desertification in the Republic of Moldova [21] systematized information on degraded lands, developed recommendations for the sustainable management of land resources and combat desertification. The program considered and identified the factors contributing to the emergence and increase of desertification. This document is also aimed at maintaining soil fertility in the risk zone for agriculture. However, there is not enough information for landowners about measures to combat desertification. There are no specific activities for local authorities and landowners for sustainable land management and combating desertification.

The law on peasant (farm) farms [22] says that land owners should not reduce soil fertility and apply environmental technologies. Landowners have obligations in law that they must comply with in relation to land cover. Currently, there is no supervisory body for the implementation of this law. The main reason for the deterioration of the land lies not in poor legislation, but in the land users themselves, who do not understand the importance of soil fertility. Therefore, the main direction in the field of land protection should be the education of landowners: clarification, study and dissemination of information about legislation to change the mentality and awareness of the importance of a natural object - soil. It is necessary to improve land and environmental legislation, which should correspond to the real state of affairs in increasing the share of eroded soils, in improving and maintaining soil fertility. There is no liability in the Law for damage to the land.

Table 5. Soil fertility and protection issues in laws and programs.

Norms and programmes	Proposed measures
Law on State Land Management, State land cadastre and land monitoring	Providing local public administration bodies, as well as citizens with information: ¤On the legal status of land plots; ¤On quantitative and qualitative parameters of land plots; ¤On the economic evaluation of sites; Other information characterizing the properties of land resources.
National Action Program to Combat Desertification in the Republic of Moldova	¤Development and implementation of measures to combat desertification; ¤ Maintaining the fertility of soils subject to desertification; Creation of the state information system of soil quality.
Law on Peasant (Farmer) Farms	Prevention of soil fertility decline, application of environmental technologies.
Law on the standard price and procedure for the purchase and sale of land	Calculation of soil quality (bonitet) of a land plot and its price.
Regulations on the import, storage, sale and use of phytosanitary products and products that increase soil fertility	Regulations governing the import, storage, sale, and use of phytosanitary products and products that increase soil fertility.
Law on ecological agricultural production.	¤ Preservation and improvement of soil fertility; ¤ Promotion of healthy nutrition; Satisfying the market in ecological agricultural products.
Sampling methodology for official control of pesticide residues on and in plants and plant products, with appropriate amendments and additions.	Sampling methods for the official control of pesticide residues on and in plants and products of plant and animal origin, the use of European sampling methods for the official control of pesticide residues on and in products of plant and animal origin are proposed.

Program for the conservation and improvement of soil fertility for 2011-2020"	¤Creation and improvement of the scientific and technical base to ensure the implementation of works on land reclamation and its constant updating ¤Creation of information system of soil quality and continuous updating of the database ¤Prevention of active forms of soil degradation on the area of 100 thousand hectares of land ¤ Implementation of methods for preserving and improving soil fertility on an area of 100,000 hectares
The Concept of the Information System "Register of Soils of the Republic of Moldova"	Creation of a database on the main indicators and parameters of the soil, its assessment and bonitet; Providing information to consumers.
Environmental Strategy for 2014-2023 and Action Plan for its implementation	Ensuring the sustainable growth of agriculture and the food industry, and, accordingly, in improving the quality of life in rural areas by increasing the productivity and competitiveness of the sector.
Low Emission Development Strategy of the Republic of Moldova until 2030 and action plan for its implementation	A set of measures that will contribute to the reduction of greenhouse gas emissions, quantifying the corresponding emission reduction for each measure.
Regulation on the Prevention of Water Pollution from Agricultural Activities	Operation of a laboratory for the determination of pesticide residues in plants, soil and plant products. The procedure for identifying polluted waters as a result of agricultural activities, identifying and delimiting vulnerable zones.
Decree on the organization and activities of the National Agency for Food Safety	Ministry of Health, Labor and Social. protection should provide the National Food Safety Agency with information from its database of food profile units subject to state food safety supervision.
Environmental performance audit	Assessment of the situation on water supply and sewerage of settlements to preserve groundwater and soil from pollution, carried out by the physiological needs of the population.

The Program for the Preservation and Improvement of Soil Fertility for 2011-2020 [23] is aimed at afforestation, the construction of lakes, deepening channels of small rivers, the acquisition of resource-saving equipment and other activities. However, afforestation, the construction of lakes, and the deepening of the channels of small rivers are not direct measures to restore and preserve the fertility of the soil cover.

The funds of this Program should be directed to the restoration and preservation of soil fertility, to anti-erosion projects, to projects to maintain fertility. Currently, a corrected soil survey is needed, using geoinformation technologies, to develop anti-erosion measures, as well as an agrochemical survey with laboratory analytical analyzes, to establish a qualitative assessment of soils and recommendations for maintaining soil fertility.

The concept of the Information system "Register of Soils of the Republic of Moldova"[24]. Within the framework of the Program for the Conservation and Improvement of Soil Fertility in Moldova, it was planned to create an information system for soil quality and constantly update the database. As a system for collecting, processing and providing information, the information system "Register of Soils of the Republic of Moldova" provides for the solution of the following issues:

- Creation of a database on the main indicators and parameters of the soil, its assessment and bonitet;
- Providing information to consumers.

The information system "Register of Soils of the Republic of Moldova" provides for the provision of information on soil quality for taxation purposes. The next document that addresses the issues of soil degradation is: Low Emission Development Strategy of the Republic of Moldova until 2030 [25]. This strategy contains a set of measures that will contribute to the reduction of greenhouse gas emissions, quantifying the corresponding emission reduction for each measure. Clause 2.5. of this strategy speaks about the contribution of the agricultural sector to low-emission development and the problems identified in this sector.
The program contains the following measures that directly or indirectly contribute to the achievement of this goal:

a) use of green fertilizers (legumes mixed with cereals);
b) adding plant residues to the soil;
c) optimization of fertilizer application;
d) crop rotation;
e) addition of legumes to crop rotation[25].

To reduce carbon losses in agricultural soils and, consequently, improve agricultural productivity, it is necessary to reduce fallow lands (wastelands), increase and reproduce soil fertility, including degraded soils, combat soil erosion and use poorly productive lands, and introduce sustainable practices to improve soil fertility by applying manure, as well as adding plant residues to the soil. Other components of sustainable agriculture, such as agro-forestry practices, integrated cropping practices through the application of green manure, are also effective in terms of mitigating greenhouse gas emissions. Another condition for the transition to sustainable agriculture is to reduce the number of tillage (introduction of conservative tillage systems: "mini-till" and "no-till"). The integrated application of sustainable agricultural practices ensures the restoration and improvement of soil fertility, increasing the productivity of the crop sector, respectively, a more balanced ratio between the crop and livestock sectors, thereby contributing to a significant reduction in greenhouse gas emissions from agriculture.

Regulation on the Prevention of Water Pollution from Agricultural Activities[26], which establishes the procedure for identifying polluted waters as a result of agricultural activities, as well as identifying and delimitation of vulnerable zones; a period is established during which the application of fertilizers to the soil is prohibited; the features of the use of fertilizers in areas with steep slopes are noted; limiting the use of mineral fertilizers in areas saturated with water. It is also noted that in order to prevent environmental pollution as a result of agricultural activities, the central public administration authority in the field of agriculture, together with the central public administration authority in the field of the environment, should develop draft action programs that provide for the following aspects:

- periods during which the use of certain types of fertilizers in the soil is prohibited;
- the capacity of the manure storage tanks, which should not exceed the required storage capacity for the longest period in which the application of fertilizers to the soil in vulnerable areas is prohibited;
- limiting the application of fertilizers to the soil, in accordance with good agricultural practices, in accordance with article 18 of the law on phytosanitary products and products that increase soil fertility No. 119-XV of April 22, 2004.

Paragraph VI "Measures to prevent water pollution by plant protection products" notes the need to inform the public about the impact, risks and potential acute and chronic consequences for human health and the environment associated with the use of phytosanitary plant protection products, and the need to use non-chemical protection products.

Also, the Decree contains many aspects for the prevention of water and soil pollution as a result of agricultural activities that farmers and landowners, including those engaged in organic farming, need to know about the prevention of soil pollution. Environmental inspectorates need to monitor this area. The regulatory act on the regulation of ensuring the fertility of agricultural land[27] establishes the need to adopt public targeted programs to ensure the fertility of agricultural land and provides for forms of support by the authorities for the restoration and reproduction of the fertility of agricultural land.5. Methods for determining the volume of soil loss from water erosion A significant increase in arable land over the past half century has contributed to the activation of erosion processes. This, in turn, served as an impetus for research on the quantitative assessment of individual erosion parameters, the volume of eroded soil under various soil and climatic conditions, and the development of measures to protect agricultural land from erosion.

An analysis of Moldova's experience in protecting soils from erosion shows that the main reason for the ongoing destruction of soils is that anti-erosion measures are often not carried out in full and not in strict accordance with the natural conditions of the territory. Measures to protect soil from erosion on the lands of collective farms, state farms and other agricultural enterprises were carried out on the basis of land management projects. Due to the lack of a sufficiently reliable calculation method for determining the washout on slopes, anti-erosion measures were designed without elementary calculations to justify them. However, they were often not carried out by land users for various reasons.

A large amount of work has been done in the republic to assess the territory in terms of erosion hazard based on aggregated indicators (Fedotov, 1976; Konstantinov, 1976, 1993), which provide general results and are usually used for comparative analysis, determining the most erosion-hazardous regions and the purpose of a more objective distribution of financial and material resources for carrying out soil improvement measures. However, it is not possible to use them to develop the necessary set of anti-erosion measures for a ravine catchment area, slope or slope section due to their insufficient specificity.

The basis for the design of anti-erosion measures should be a quantitative assessment of the erosion hazard of land - potential washout (t/ha per year), calculated taking into account the influence of climate, relief, soil, vegetation for slopes, gullies or the entire territory of the farm unit. Depending on the magnitude of the erosion hazard of the lands, the structure of lands and cultivated areas is specified, the system of crop rotations, fields, working areas, road network and other elements of the system of anti-erosion organization of the territory are designed. The criterion for evaluating the effectiveness of work, both individual methods and their entire complex, should be the allowable erosion, that is, the amount of washed off soil that can be restored by the soil-forming process.

Below are some analytical and empirical dependences for determining soil losses (washout), reflecting the specific patterns of formation of atmospheric precipitation runoff and soil washout from slopes. These dependencies are widely used in practice. In the future, we will show this in relation to the conditions of Moldova.

4.6 Methods for determining the volume of soil loss from water erosion

4.6.1 Calculation of the amount of eroded soil according to the method of Ts.E. Mirtskhulava

The proposed method for predicting soil washout, along with their resistance to erosion (estimated by the value of bed-load transport rate), precipitation intensity, infiltration capacity, and hydraulic runoff parameters, takes into account the relative influence of crop rotation and agricultural practices on this process. The amount of soil washed off from a site having a unit width and length from the watershed to the end of the eroded part of the slope is determined by the following relationship (Mirtskhulava, 1978):

$$q_{X_2} = 11 \cdot 10^{-7} \gamma \omega d \left[\frac{308 \cdot (\sigma n_0)^{0.6} \cdot i^{0.7} \cdot m_1^{1.4} \cdot I^{0.6} \cdot X_2^{1.6}}{V^2_{\Delta доп}} + \frac{13 \cdot 10^{-6} V^{3.32}_{\Delta доп}}{(\sigma n_0) \cdot i^{1.16} \cdot m_1^{2.32} \cdot I} - X_2 \right] \cdot T \left(\frac{т}{м} \right) \quad (1.1)$$

Soil washout in tons per hectare is determined by the formula:

$$q_{X_2} = 11 \cdot 10^{-3} \gamma \omega d \left[\frac{308 \cdot (\sigma n_0)^{0.6} \cdot i^{0.7} \cdot m_1^{1.4} \cdot I^{0.6} \cdot X_2^{1.6}}{V^2_{\Delta доп}} + \frac{13 \cdot 10^{-6} V^{3.32}_{\Delta доп}}{(\sigma n_0) \cdot i^{1.16} \cdot m_1^{2.32} \cdot I} - X_2 \right] \cdot \frac{T}{X_2} \left(\frac{т}{га} \right) \quad (1.2)$$

where γ is the bulk density of the soils in a state of complete water saturation, t/m3; d is the average size of aggregates (separated units) reduced to the diameter of an equal-volume sphere (Mirtskkhulava, 1965) in the absence of data from special studies, the aggregate size is assumed to be d = 3 + 5 mm: on average, d = 0.004 m.

According to Moscow State University, for arable soil horizons , developed on moraine and loess-like loams for soils of the plain territories of the European part of the former USSR, the value of d does not xceed 1-2 mm, and on average it is 0.5 mm;

VΔdop ~ allowable bottom non-erosion velocity of the water flow;

ω- average frequency of pulsation speed. It can be set by the Strouhal number;

$$\omega = 0{,}73V / H \tag{1.3}$$

V - average slope runoff velocity;

H is the depth of the runoff.

In the absence of data from special studies, the value (o is taken equal to 10 1/s;

I - average intensity of precipitation, m/s;

T is the duration of excess precipitation or the time during which the layer of precipitation exceeds the layer of infiltration;

σ - runoff coefficient;

n0 - coefficient of hydraulic resistance (Manning coefficient);

i - average slope of the surface, equal to the ratio of the level difference to the horizontal equivalent;

X2 - distance from the watershed to the end of the eroded part of the slope,m;

m1- coefficient that takes into account the deviation of the nature of the movement of slope runoff from the movement of an equal layer of water (water shroud) accepted in the analytical model, according to A.N. Kostyakov (1960), a coefficient characterizing the wrinkling of the slope surface, the concentration of runoff.

For approximate calculations, according to A.N. Kostikov we can take as an axiom that

$$m_1 = 1{,}2 \div 3{,}0.$$

For practical calculations, the coefficient m1 can be differentiated as follows: for a carefully leveled slope with transverse plowing - 1.5, longitudinal - 2.0; for a moderately leveled slope with transverse plowing - 2.0, longitudinal - 2.5; for a poorly leveled slope during transverse plowing - 2.5, longitudinal - 3.0.

A very important point in calculating soil losses is the determination of the length of the non-eroded section of the slope, since the erosion equation makes sense (gives logical results) only when the length of the section of active erosion Lact = X2 – X1 is a positive value, where X1 is the length of the initial non-eroded section of the slope. Therefore, before calculating the soil washout from the slopes, the length X1 must be preliminarily set according to the formula:

$$X_1 = \frac{34 \cdot 10^{-6} V_{\Delta доп}^{3.32}}{m_1^{2.32} \cdot i^{1.16} \cdot (\sigma n_0) \cdot I}$$

4.6.2 Method for determining soil loss according to RUSLE (USA)

To determine the amount of soil lost during heavy rainfall, the United States uses the Universal Soil Loss Equation - USLE (Universal Soil Loss Equation), which was developed on the basis of an empirical relationship proposed by Wischmeier and Smith (1958,1965) and improved in subsequent years.The first version of the USLE was described in Agricultural Handbook No. 282 (1965); second version in Handbook No. 537 (1978). The Revised Universal Soil Loss Equation (RUSLE) is the third version of the USLE that has been extensively revised and published by the United States Department of Agriculture (1991) [48].

RUSLE provides for the determination of the average long-term value of soil loss according to the following relationship:

A = R x K x L x S x C x P

where A - average estimated amount of soil loss per year per area unit (t/ha*year);

R - erosion hazard factor of precipitation (rain eroding capacity) ((MJ*mm)/(ha*hour*year));

К - factor of soil erodability or soil susceptibility to erosion ((t*ha*h)/(ha*MJ*mm));

S - slope steepness factor;

L is the slope length factor;

C - factor of vegetation cover and crop rotations;

P - factor of anti-erosion measures.

The energy of torrential precipitation is calculated on the basis of data obtained from the registration of rain characteristics on a pluviograph tape. Mathematically, R is expressed by the dependence:

$$R = \frac{1}{n} \sum_{j=1}^{n} \left[\sum_{k=1}^{m} (E)(I_{30})_k \right]$$

where E is the total kinetic energy of the shower;
I - maximum 30-minute intensity of this rain, mm/hour;
J - index indicating the ordinal number of the accounting year;
n - index of the number of years taken in the calculation;
K is an index indicating the ordinal number of rain in a year;
m is the number of showers that fall annually.

There are a number of dependencies that determine the amount of soil erosion (Gizr, 1989; Surmach, 1980, 1979; Shvebs 1970; GOST, 1986). Some of them gravitate to the hydrological type of the model and are used in calculations of the amount of surface runoff from agricultural lands at different levels of precipitation. Most of the quantitative indicators and correction factors used in the equations (Surmach, 1980, 1979) to determine the amount of runoff were developed for the climatic conditions of the central chernozem regions of Russia, where melt waters play an important role. Therefore, their use for the conditions of torrential precipitation on the territory of Moldova is limited and is omitted by us.

State Standard (GOST) - Method for determining the potential risk of erosion due to rain (1986) uses the same factors as the equation of Wischmeier and Smith (1965, 1978). However, to determine some parameters, it is necessary to use the results of direct measurements of the amount of washed soil from the slopes occupied by crops and standard runoff areas on black fallow. This causes certain difficulties in its practical application.

The methods described above (Mirtskhulava, 1978; Methodological instructions..., 1989; Vishmayer, 1978) can be used to determine soil losses from erosion for the conditions of Moldova, respectively, introducing certain adjustments for individual coefficients included in the calculation equations. In developing methodological recommendations for determining soil runoff parameters, some authors used approaches and individual parameters taken from the Universal Soil Loss Equation (USLE). So, Ts.E. Mirtskhulava (1978), when assessing the influence of crops on the intensity of erosion in different periods of their development, used some data from Vishmaier and Smith. The authors of the methodology developed by the State Institute of Land Resources (GIZR, 1989) used, with some modification, approaches borrowed from the same method to determine the erosion potential of heavy rains and the relief factor.

The application of the Improved Soil Loss Equation (RUSLE) on the territory of the republic requires its adaptation, like any other, in relation to local conditions. However, despite the apparent cumbersomeness, it differs from other similar dependencies in greater specificity in the selection of starting materials and in the most complete development of its constituent coefficients. From a practical point of view, the value of the proposed methods lies in the fact that they provide quantitative parameters used to design erosion control measures and assess the potential risk of erosion under various conditions of use of sloping lands.

4.7 Practical experience

A good example of reduced soil erosion is a chernozem slope with varying degrees of erosion in the Cahul area, Lebedenko commune, used in agricultural production (photo 1). A scientifically substantiated system of developed anti-erosion measures, for a specific relief of the territory, made it possible to preserve the fertility of sloping soils. This model of strip cultivation of agricultural crops, the use of special agrotechnical methods of tillage and the developed anti-erosion measures have reduced soil erosion to acceptable limits. This experimental site of the Institute of Soil Science, Agrochemistry and Soil Protection "Nicolae Dimo" is demonstrated not only at the republican, but also at the international level.

Assistance in the promotion of ecological farming on the two banks of the Dniester is provided by the international organization "Eco-Tiras" [http://www.eco-tiras.org/] implements international projects in which non-governmental environmental organizations of the two banks participate, which carried out projects within the framework of the Ramsar convention "Restoration, Rehabilitation and Implementation of Protective Measures in the Core Wetland Areas in the River Dniester Downstream in Moldova" (2001-2002), project "Biodiversity conservation in the lower Dniester Delta Ecosystem" (2001-2004). Every year, the Eco-Tiras NGO publishes a lot of information on environmental education, scientific literature on the environmental problems of the Dniester, and also organizes environmental summer camps, in which young people from both banks participate.

Photo 1. Anti-erosion organization of the territory of the room. Lebedenko, Cahul district (Photo: G.P. Dobrovolsky).

4.8 Possible approaches and methods in the field of agriculture and soil protection

An analysis of the current state of development of agricultural production in the country confirms the need for a set of measures to stabilize and restore soil fertility of agricultural land, as well as improve the overall environmental situation. Increasing the soil fertility of agricultural land is a natural condition for the intensification of agriculture, contributes to the growth of productivity, increases the value of land, and is of great environmental importance. The components of soil fertility conservation for agricultural land are very multifaceted and represent a combination of a wide variety of factors that affect the potential return of agricultural land in the form of a crop. To create a mechanism for the preventive conservation of the natural fertility of soils based on balancing the rates of their exploitation and self-recovery, it is necessary to take into account the most important law of agriculture, justified by J.Liebig, which says: to maintain soil fertility, a balance of nutrients must be maintained. The amount of nutrients that is alienated from it with the harvest should be returned to the soil annually. It will not be possible to fully compensate for the losses by applying mineral fertilizers alone, because the plant absorbs microelements, biologically active substances, amino acids and a number of other ingredients that are part of its nutrition system. The optimal solution would be an annual application of organic fertilizers, but with the current state of animal husbandry, this is not possible.

The easiest way is to use natural ways to restore fertility through the use of green manure and incorporation of straw to enrich the soil with organic matter, the cultivation of perennial legumes to restore soil structure and enrich them with nitrogen, the introduction of minimal or no tillage, i.e. the so-called No-Till technology. Reproduction of soil fertility in modern agriculture is carried out in two ways: material and technological. The first involves the use of fertilizers, ameliorants, pesticides, etc., the second - crop rotation, catch crops, various methods of tillage and sowing methods, etc. These ways are aimed at achieving a common goal, although their mechanism of action is different.

4.8.1 Alternative farming aiming to preserve soils

Alternative farming is a paradigm aiming to obtain agricultural products that do not contain residual amounts of agrochemicals, as well as to preserve soils and their fertility. The concept of alternative farming is more complex: agrotechnical measures are considered in combination with all possible consequences for the soil, flora and fauna. Soil is considered as a living organism with complex physicochemical and biological processes, including soil-dwelling organisms and microorganisms.

In alternative farming, it is considered necessary to fertilize the soil, not the plants: the principle is based on: "From healthy soil to healthy plant, animal and person."

- Preservation of the original soil structure and edaphon, which stimulates the biological activity of the soil, increases humus.
- Each soil horizon has its own edaphon.
- The edaphon of each horizon requires specific living conditions (humidity, pH, mechanical composition, temperature, etc.)
- Tillage is considered an intervention in this complex system. Recovery takes a long time.
- Manure application.

Organic agriculture is also used in Moldova in order to prevent erosion and increase soil fertility. However studies found that within two years the physical properties of soils treated by no-till farming technique had deteriorated: the soil became highly compacted and highly resistant to root penetration, starting from a depth of 5-6 cm from the earth's surface. Only the top layer of soil 0–5 (6) cm remained very loose, consisting of a mixture of organic residues and glomeruli of fine earth.

Therefore, methods were studied for the preventive restoration of the properties of the degraded arable layer of ordinary chernozems by the systemic use of green manure in combination with various agrotechnical measures for the case of basic tillage according to No-till and / or Mini-till technologies [28]. Measures of anti-erosion protection during the main tillage, as well as to preserve and improve the fertility of eroded soils, the production of organic fertilizers from animal waste and the application of organic fertilizers are described in detail in the instructions for farmers of the Republic of Moldova [29]. There is also a practical guide to ecological farming (field crops) [30], which reviews the technological features of crop cultivation in ecological farming system.

4.8.2 Conservative Agriculture

Transforming farming systems to sustainability while, at the same time, delivering food and water security, faces big challenges. To mention just three: arresting land degradation, building soil fertility and adapting to climate change. If there is a way, it must be by the systems or holistic approach advocated by Giller et al. (2015). Conservative agriculture (CA) is just that. Its principles are:

- *No mechanical soil disturbance*—by seeding directly into untilled soil so as to maintain the architecture of the pore space and minimize loss of soil organic matter;
- *Permanent, permeable ground cover*—by crop residues that protect the surface from sun, wind and rain, and which also fuel the life of the soil;
- *Crop diversification*—through rotations or associations of crops that control weeds, pests and diseases.

The new paradigm works almost everywhere for the simple reason that it eliminates destructive disturbance of the living soil and daily attack by the elements. At the same time, it conserves water resources:

- *Maximum infiltration of rain and snowmelt* by a permeable surface protected r dense vegetation or surface mulch. This cuts runoff, erosion, and flash floods
- *Maximum water retention* by well-structured, humus-rich soil that is deeply rar~- ified by roots. This builds resilience against drought and availability of water and nutrients throughout the soil profile, not just the plough layer.
- *Percolation of surplus water* through coarse pores, root runs and worm burrow to replenish the groundwater and, in dry weather, *continuous ascent of soil water* to the root zone.

Pros and Cons

CA pros and cons. Among the pros:

- Much-reduced costs of production: less labour, less fuel, less machinery and. r. the same time, comparable or better crop yields;
- Increased soil fertility, including crop health and water and nutrient balance, which gives more sustainable yields with less need for costly industrial inputs;
- Arrest of soil erosion, so less sediment in streams and reservoirs;
- Greater infiltration of rain and snowmelt, less runoff, so better recharge of ground water;
- Less contamination by toxic substances and less leaching of nutrients into surface- and groundwater, so flourishing aquatic ecosystems;
- Increased soil biodiversity as a result of diverse crop rotations and less soil disturbance;
- Less emission of greenhouse gases;
- More carbon capture;
- Less flooding, damage to infrastructure and drying up of reservoirs.

Cons, often seen as obstacles to adoption of CA, include:

- The need for special planters. CA pioneers had to adapt their existing equipment, especially for direct seeding, but as CA has spread worldwide, manufacturers ham e embraced the new market. A range of direct drilling and planting machinery . now widely available.
- Problems with weeds, pests and diseases and concerns about chemical sprays:
- Lack of knowledge and new management skills (Stagnari et al. 2009)

The advantages of timely deployment of the mouldboard plough are:

- Weeds, pests and diseases are controlled by breaking their life cycle, but only briefly;
- Creation of a seedbed for uniform germination and crop establishment;
- Increased contact of the mineral part of soil with decaying organic material for better humification and release of plant nutrients. *This can also be a disadvantage* (Goldstein and Boincean 2000; Triplett and Dick 2008; Dick 1984).
- Faster warming of the soil in the spring;
- Breakup of surface crusts and subsurface compaction for improved infiltration but, again, only briefly.

Disadvantages:

- Costly consumption of fuel and labour;
- Exposes the soil to erosion by removal of protective crop residues and loss of soil structure;
- Disrupts the habitat and life cycle of earthworms and myriad other beneficial species;
- Disrupts drainage and upward flux of soil water;
- Compaction at the plough sole;
- Increased drying of the topsoil, especially in drought years.

Tillage can also improve the condition of the soil—but only for a short time (Sidorov 1981). It can mobilize nutrients and even increase yield—but it diminishes soil fertility, as we have seen in the trans formation of fertile virgin steppe into worn-out soil (Sokolovsky 1956) ; and by hastening the breakdown of soil organic matter, it also breaks down the resilience of soil aggregates—leaving the soil vulnerable to erosion [30].

4.9 Territory pollution.

As a result of our field studies, starting from 2020, pollution sources were identified in the project area in the settlements of Budesti and Cruzesti. However, there have been positive developments in the direction of elimination of pollution points. According to the news published at the beginning of 2021 in the municipality of Chisinau in the settlements of Budesti, Colonita, Cruzesti and Tohatin, the mayor's offices of these settlements signed a cooperation agreement. It will allow faster and better resolution of the problems of the residents of the suburbs, and this is more than 14,000 people. Through the agreement, it is planned to introduce projects to improve infrastructure and implement social projects. Thus, the Budeshty will now be able to become a beneficiary of the "My Community" program supported by USAID. The first project, which is planned to be implemented, concerns the removal of municipal solid waste. It is necessary to purchase two trucks that will take out garbage from four settlements. [31]

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Ch. 5 A Review of Best Management Practices for Reducing Pollutants and Litter in the Black Sea

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5.1 Introduction

Pollutants and litter that originate from the watersheds that flow into the Black Sea need to be reduced. Until now, the majority of the efforts in the Black Sea Basin have focused on actions taken in the sea or along the seacoasts. The majority of the pollutants and litter originate from river freshwaters that end up in the sea in many cases. When the priority task is to reduce the rate of eutrophication of the sea, many countries in Europe focus management efforts primarily on reducing pollutants in the river catchments. The Rhine basin in Europe, for example, has managed to reduce the amount of phosphates in the river by half in the last 15 years. This has had a hugely positive impact on the region's ecology, with many people expecting the Rhine's waters to reintroduce salmon and other fish species that had been thought to be extinct for decades.

To ensure that the best management practices are both sustainable and cost-effective, the various sources and their contributions must first be identified. This will be accomplished by employing new scientifically sound technologies such as fingerprinting methods, drones, laser scanning, and hydrologic models in various land-use scenarios applicable to the entire Black Sea basin. Furthermore, because most point source pollutants originating from industry and municipalities have been reduced through legislative measures, the non-point source pollutants which are more difficult to detect because they cannot be pinpointed at a specific location but have proven to provide the majority of the pollutants. Finally, because small streams and channels have more direct contact with the watershed, they are commonly considered and referred to as the production zone, which is where the majority of sediment, nutrients, and litter originate. This is also due to the fact that small streams in widths have longer stream lengths in total than long rivers and are more likely to receive non-point source pollutants.

Once the major sources have been identified, target approaches will be used to recommend what and where the best management practices should be placed. According to studies, establishing best management practices in areas that produce the highest 10% of non-point source pollutants can result in a reduction of. This will result in the most effective use of the limited funds available for conservation practices.

Best management practices to be considered include reestablished riparian forest buffers, restoration of natural wetlands, soil and water bioengineering techniques, and an overall nature-based solution that can remove significant amounts of non-point source pollutants or liter traps that will increase the possibility of creating an environment for new species and protecting the region from flooding. Overall, the goals are to find solutions and implement best management practices that will maintain the region's economic growth rates while also preserving and protecting the Black Sea's ecological balance and biodiversity.

5.2 Sediment fingerprinting as an approach for identifying sediment sources in river basins

Fingerprinting method is one of the useful tools to identify sources of the sediments in the watersheds and then implement the best management practices in these areas. Fingerprinting is also a way of sediment budgeting in watersheds. Sediment budgeting shows us the source and sink areas in the watershed. Once the source of sediment is known, watershed managers may implement the best management practices for reducing sediment generation and transport. However, identifying the sediment sources and their relative contribution to waterbodies is difficult in most of the cases. Factors such as vegetation type and density, soil type, topography, land use, geology and climate may influence sediment source, transport and deposition.

One of the new methods of identifying sediment sources and the amount of sediment generated from the different sources is sediment fingerprinting. With this method, watershed managers use physical, chemical and/or biological tracers to distinguish between the types of sediment sources in a watershed and estimate how much sediment each source contributes to the stream. This method requires intensive field, laboratory and modeling work.

One of the biggest challenges in using sediment fingerprinting is the required costs and labor. Because the process is watershed specific, the most appropriate tracers and potential sediment sources must be identified for each watershed. This work requires the collection and analysis of many samples. The process of sediment fingerprinting would also benefit from a greater level of standardization. While the main components are the same, small variations are present between users.

Conventional fingerprinting methods based on geochemical composition still require a time-consuming and critical preliminary sample preparation. Thus, fingerprinting characteristics that can be measured in a rapid and cheap way requiring a minimal sample preparation, such as spectroscopy methods, can be a good choice for this purpose [45].

The technique is multidisciplinary, covering subject areas including geology, geomorphology, environmental science, soil science, oceanography, agriculture and forestry, and it is being used to answer a wide range of research questions. Table 2 summarizes some of the main applications of the sediment fingerprinting technique [18].

Table 1. Applications of the sediment fingerprinting technique [18].

Application	Example
Climate change	Gingele and De Deckker (2004)
Contaminant dynamics	Bird et al. (2010)
Criminal forensics	Dawson and Hillier (2010)
Environmental forensics	Saber et al. (2006)
Evaluation of management practices	Collins et al. (2010a)
Decision making support	Evans et al. (2006)
Nutrient dynamics	Walling et al. (2008)
Sediment budgets	Walling et al. (2002)
Contemporary sediment fluxes	Smith et al. (2011a)
Sourcing organic matter	McConnachie and Petticrew (2006)
Historical reconstruction	Dearing et al. (2001)

At present, one of the main limitations of the sediment fingerprinting approach is the ability to quantitatively link sediments back to their sources in a reliable means due to the non-conservative behaviour of the properties of transported and deposited sediment [10]. Ideally, the composition of the sediment, including geochemical (e.g., trace metal content), biological (e.g., organic matter content) and physical (e.g., texture) properties, would not change (i.e., remain conservative) as the sediment moves through the landscape such that direct comparison between sources and sediment can be made. However, this is rarely the case in reality. The changes in sediment properties that occur as the sediment moves through the watershed need to be taken into consideration [10] [18] have suggested that accounting for the fate of sediment and fingerprint properties is the least understood part of the sediment fingerprinting approach and that further future research should be directed at addressing these issues as it is critical to the advancement of the method. The processes that link the sources of sediments (e.g., cropland, channel banks) to the collected sediments (e.g., suspended sediment, channel bed sediment) are often ignored and currently represent a black-box in the sediment fingerprinting method.

A variety of chemical and physical tracer techniques have been used to investigate the sources of sediment and nutrients to river systems. These tracing techniques all involve measuring of one or more parameters that provide a 'fingerprint' to distinguish one source of sediment from another. For a parameter to be useful in tracing the source of sediment it needs to be both measurable and conservative such that:

- A tracer signal should be able to distinguish between sediments derived from different source areas;
- For a given source of sediment, which does not change with respect to time, a sediment tracer signal must also be constant in time or vary in a predictable way;
- For a given source of sediment, which does not change with respect to distance along a transport path, a sediment tracer signal must also be constant along this path or vary in a predictable way [9].

The possible sources of errors in using this method are:
(1) tracer conflicts,

(2) differential tracer measurement errors, and

(3) varying degree of the conservativeness of each tracer or lack of it [56].

However, the discrimination power of fingerprint properties for small catchments, in which the surface materials are relatively homogeneous and human interference is marked, may be affected by fragmentary or confused source information [56] [57]. For a careful assessment of the method, the fallowing steps need to be taken carefully (Table 2).

Table 2. Five main steps of sediment fingerprinting.

Step 1. Classify sediment sources
Step 2. Identify unique tracers for each sediment source
Step 3. Represent sediment sources and sinks
Step 4. Account for sediment and tracer fate
Step 5. Utilize an unmixing model for sediment source and fate

Information related about the geomorphology, hydrology and climate, land use, soils or location, among others, provide an understanding and criteria for:
1) the sampling design,

2) the potential physical and biogeochemical changes that can occur during the transport of sediments,

3) interpreting the results obtained by putting these data into the appropriate spatial and/or temporal context [19].

All sediment fingerprinting studies must decide on the choice of field sampling methods, and selection of tracers as well as mixing models. Allowing for time and budget constraints, the study objective should drive the field sampling method. For example, fluvial sampling is the preferred method to determine the origin of sediment deposited in a dam, whereas point sampling is the most appropriate method to monitor sediment contribution in a flood event. Budget will also drive the selection of tracers used as sediment fingerprint properties. Physical tracers are less expensive and can be measured easily, but they are not conservative and may lead to ambiguity in interpretation of results. Geochemical tracers are favored due to large number of elements available for sediment fingerprint measurements. Radionuclide tracers are the most powerful tracers to distinguish soils from different land uses, but need expensive instruments [13].

5.3 Drones as an approach for identifying and monitoring hot-spots

Hot-spots are major sources of pollutants and litters such as landslides, quarries and mines, cleared tea fields, tilled fields, manure fields, livestock loafing areas and blocked streams. Detecting such hot-spots with innovative techniques using remote sensed satellite imagery and images from Unmanned Aerial Vehicles (UAVs) are considered one of the best tools to identify source area of pollutants and litters from local scale to watershed scale. For example, until permanent site ground covers are built, best management techniques for erosion control are necessary throughout every ground disturbing work. A physical, managerial practice, structural, or chemical that prevents, reduces, or treats water contamination or soil erosion would be considered a best management practice.

Stormwater management is essential for preventing erosion. The stormwater BMPs listed below describe methods for transporting, diverting, treating, and generally controlling stormwater flow rates and quantities. Sizing stormwater control BMPs can be tricky, and runoff volumes and rates might be unpredictable. On all stormwater designs, it is advised that a licensed design engineer be consulted. It is both expensive and impossible to find all stormwater control stations on a watershed scale. Drones, on the other hand, can be used to detect such places [50] [7].

In agricultural areas, composted livestock feces are utilized as a fertilizer to increase crop production [16] [58]. Because of characteristics such as nutrients, suspended particles, oxygen depletion, and bacteriological quality, livestock manure that enters water systems is a major concern [22]. Because it mostly exists as inorganic phosphorus, and its quantity in manure ranges from 2600 to 40,000 mg/kg, phosphorus, one of the principal components of livestock waste, operates as a non-point source pollutant. Because 80 percent of animal excrement is water soluble, it is likely to discharge as leachate or surface runoff when it rains [40] [54].

Recently, technology has been developed for detecting various ground surface information utilizing imagery data received from satellites and unmanned aerial vehicles (UAVs), obviating the requirement for direct on-site inspection. Non-point source pollution has also been actively managed using remote sensing tools [39] [11]. Satellite photos can give you information about the ground surface across a large area. Because they collect photographs of the same region at regular intervals, they are also useful for detecting temporal changes in the properties of the ground surface (Ning et al., 2016). However, because most satellite imagery have a mid to low resolution, it is difficult to correctly identify the characteristics of the ground surface, and it is especially difficult to recognize items, such as OMP sites, that occupy small regions [36] [34].

Park et all. (2021) [33] for example, used the DJI's Phantom 4 drone to investigate outside manure piles (OMP) for effective non-point source pollution management in agricultural areas. The UAV was used to collect picture data, and ortho-images were used to identify OMP distribution and cover installation status. The authors used the digital surface model (DSM to estimate the volumes of OMP.

Researches from Canada used small drones to sample water pollutants and successfully store and carry samples to the location to be analyzed [12]. A real on-site sample was taken from a probable landfill-impacted watercourse south of London, Ontario. One 4 cm and one 2 cm HLB/PDMS TF-SPME membranes were mounted to the drone to enable for instant on-site analysis utilizing portable GC–MS instrumentation, as well as the opportunity to undertake a comparative analysis once back in the lab using tabletop instrumentation. Before retrieval, the drone TF-SPME sampler performed extractions for 10 minutes on the stream's surface [12].

Figure 1. A landslide photo next to a forest road caused by unsupported removal of toe and absence of supporting side wall (photo by Mehmet YAVUZ)

Another research was conducted in Clemson, SC, USA by Koparan et al. (2018) [20] to measure surface water quality on a small agricultural pond. They tested a custom-built six winged UAV with a license free electronic sensors framework to analyze the dissolved oxygen (DO), electrical conductivity (EC), temperature, and pH of water. Soundkeeper Bill Lucey from Wilton, Connecticut, USA, used a small drone to monitor ecological changes due to dam removal in Merwin Meadows Park. For decades, the Strong Pond Dam, also known as Merwin Meadows Dam, has beenobstructing sea-run fish and altering sediment movement. After the removal of the dam, Mr. Lucy utilized drone to map out the current conditions of the river [51] [52].

Reany et al. (2019) employed drones to identify sites using data acquired using a bespoke phone application from an onsite survey and using UAV images to produce a high spatial resolution DSM and land use and land cover map in the Newby Beck tributary of the River Eden, Cumbria, UK. The researchers evaluated each approach's effectiveness in terms of possible improvements in diffuse pollution risk identification, associated costs, and utility in mitigation planning and management. They suggested that a multi-evidence based strategy to diffuse pollution control be implemented across catchment spatial scales, merging local knowledge from the walkover with the varied data resolutions of the SCIMAP approach, based on the findings in their study.

In the United States, [17] studied the sediment production of forest roads. They measured the annual downslope deposition of granitic sediments degraded from forest roads built on three headwater basins in central Idaho, United States. The source and location of the deposit terminus were used to identify sediment deposits. A total of 1,659 m^3 of sediment was deposited on slopes from the 6.6 km of roads during four-year research period, with 70% of the total occurring in the first year after construction. There were 335 sediment deposits measured, with 85 percent coming from diffuse erosion on fill slopes and 8% from cross drains.

We noticed that the roads in the Arhavi River Watershed were built very close to the streams (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**). When erosion or sediment movement is connected with dispersed road runoff or hillslope erosion from rain or dry ravel, keeping a safe distance between roads and streams is likely to be the most effective BMP [17]. BMPs for forest roads, for example, include a side wall next to the road to support the toe of a vulnarable landslide (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**). Detecting such roads and landslide with the help of GIS and Remote Sensing is considered a good practice of BMPs.

Many streams are not accessible due to the sharp deep cuts, heavy understory vegetation such as rhododendron and cherry laurel (Prunus laurocerasus). The bank stability and streams conditions are hard to detect within these kinds of heavily vegetated areas. Such streams are also not wadeable to inspect the stream bank conditions. Unmanned Aerial Vehicles (UAV) comes very handy on these kinds of situations. Inspecting unreachable reaches can be done effectively with UAV (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**). Many streambank indices can be extracted from ortho-photos and DEM that derived from UAV imagery. A stream bankfull width, bank angle, bank height can be measured and extracted from the DEMs. The baseflow borders, bank bars, pools and aggregated islands can be detected, delineated and measured using UAV derived ortho-photos.

Figure 2. A streambank erosion that threatens the nearby paved road in the Kamilet Valley, Arhavi, Turkey (Photo by M.Yavuz 2021)

Figure 3. A stream bank made up of very steep cliff that prevents entering the stream channel in Gorci Tributary of Arhavi River (Photo by M. Yavuz,2021).

5.4 Hydrological models as an approach for identifying sediment sources

Physically-based modeling tools (SWAT, WEPP etc.) can be used to predict the discharge of the streams as well as identifying the potential stream networks with the available water resources and attached pollutants [2] [28]. The model used in this project to predict potential streamflow and attached pollutants is the Soil and Water Assessment Tool (SWAT). It is a public domain model developed by the USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research [2]. The SWAT is widely used in regional watershed management to identify and reduce soil erosion and non-point source pollution in watersheds [8]. With a variety of physical and chemical models, SWAT can simulate runoff, evaporation, groundwater, rainfall and other hydrological processes [30]. The SWAT model as a new innovative technique can also be used to identify the most suitable locations for water reservoirs to suppress wildfires [47].

The SWAT can be managed within the Geographic Information Systems (GIS) through the interface named ArcSWAT. The interface requires information about the morphology of the watershed based on the Digital Elevation Model (DEM), soils, land-use and weather data. The water budget equation that SWAT uses is the following:

$$SWt = SWo + \sum_{i=1}^{t} (Ri + Qi + ETi + wi + Gi)$$

where t is the simulation period, SWt is the soil water content after the simulation period, SW0 is the soil water content at the beginning of the simulation period, and Ri, Qi, ETi, wi and Gi are daily values for precipitation, runoff, evapotranspiration, percolation and return flow from the soil profile [29]. The configuration of SWAT uses field elevation and optional flow data to identify sub-basins within respective basins. Sub-basins are spatially distributed, and streamflow and associated contaminants are routed from one sub-basin to another. The hydrologic portion of the SWAT requires the identification of the major streams for the prediction of the water budget and stream discharge but also field measurements of discharge in order to calibrate the estimated results produced by the model.

In the SWAT configuration, the availability of daily temperature records suggested the use of the Hargreaves method to estimate evapotranspiration [5] [14]. The run-off curve number method was employed to estimate surface runoff from precipitation and the variable storage method was used to simulate channel water routing

The use of the SWAT model in assessing the water budget has been proven to be a suitable tool by numerous researchers [8], but its application for water resources in the use of wildfire suppression has not been implemented. However, due to the uncertainty in many water budget parameters, the calibration of the SWAT models is a continuing challenge. An automated calibration is another option in the SWAT-CUP software [1].

5.5 BMPs to reduce pollution and litter

5.5.1 Multi-species riparian buffer systems

Intensive agricultural land-use, including row-crop cultivation and pasture grazing, is a major contributor of sediment and phosphorus to aquatic ecosystems [37]. While row-crop cultivation is often considered the more important contributor of the two, in some cases, watersheds with a higher proportion of grazed pasture, may contribute more phosphorus to streams than a watershed with greater proportions of land with other agricultural uses. It has been observed that areas known as critical source areas (CSAs) within the agricultural landscape have a very high potential to contribute sediment and phosphorus because of their unique locations close to streams [40] [41]. The consideration of CSAs within the agricultural landscape can explain a large portion of the sediment and phosphorus load to surface water. Focusing on livestock stream bank access points and loafing areas as important CSAs within riparian areas is essential to reducing the sediment and P loads to receiving waters [55].

In-field conservation practices are usually not sufficient to meet the requirements for significant nutrient removal from agricultural land to streams. A riparian forest buffer is specifically defined as:
"an area of trees, usually accompanied by shrubs and other vegetation, that is adjacent to a body of water and which is managed to maintain the integrity of stream channels and shorelines, to reduce the impact of upland sources of pollution by trapping, filtering and converting sediment, nutrients, and other chemicals, and to supply food, cover, and thermal protection to fish and other wildlife [32]".

Riparian forest buffers and grass filters have the potential to capture non-point source pollutants by slowing surface runoff, trapping sediment, and providing high soil water infiltration [37, Figure 4]. Buffer strips, located along streams have the potential to sequester C from the atmosphere, immobilize N in biomass and trap sediment and nutrients before they reach the stream, reducing livestock impacts thus, improving water quality not only for human needs but also for other organisms and animals that rely on them [46]. The soils of buffer strips have high water infiltration [3] and soil organic matter content which is considered to be an important soil quality indicator in terms of soil erosion resistance [26]. Phosphorus loads can be reduced as much as 95% by buffer strips that are 10 m wide [23] [48]. Denitrification rates have been found to be high within riparian buffers on soils with high water tables. With buffer strips, the residence time of the shallow ground water increases as it passes through the soil, increasing denitrification [25]. Buffers also stabilize stream banks and improve the aquatic habitat for both invertebrates and fish [24].

Stainton et al. (2003) [44] stated that soil hydraulic condition plays an important role in defining buffer zones and buffer effectiveness. Riparian buffers with sandy soil, dominated by subsurface drainage systems, are less likely to reduce sediment and nutrient loading to streams from the agricultural land [27]. Therefore, buffers should not be used as an initial management practice to control nutrient loading to streams without detailed knowledge of the hydro-geologic environment [43]. In addition, trees and shrubs in the riparian zone show great potential of increasing soil water storage by plant water uptake [4] [6] so that dewatering of the soil by buffer vegetation provides more soil water storage for runoff events.

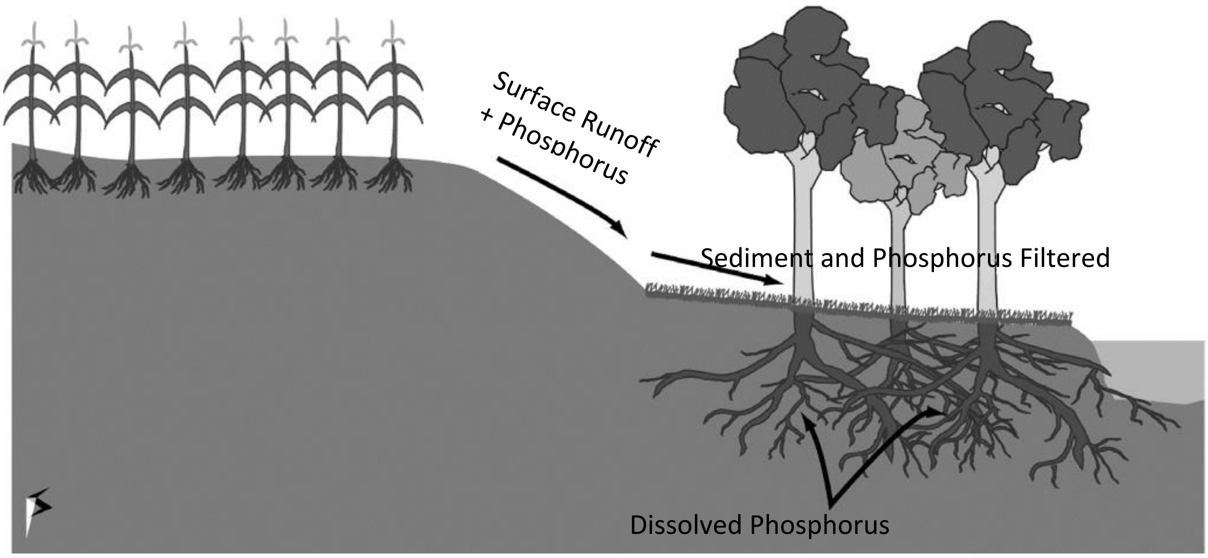

Figure 4. Riparian forest buffers filter sediment and attached phosphorus from surface runoff [38].

5.5.2 Instream and Streambank Stabilization Erosion Control Best Management Practice

Instream BMPs are meant to capture sediment for projects that must be completed within the canal. Any projects that cross or work inside the canal should make every effort to keep the amount of work done within the waterflow line to a minimum.

Constructions from bank zones, stream redirection around construction sites, and timing for seasons with no limited flows are all options for reducing the amount of instream work required [49]. To protect streams, banks, and in-stream habitat from rapid erosion, streambank stabilization employs a combination of erosion and sediment control techniques (**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**). Protection of existing vegetation, permanent and temporary seeding, check dams/grade control, rolled erosion control products, outlet protection, temporary diversions, dewatering operations, and bioengineering practices like fascines, live staking, brush layering, and are all examples of BMPs associated with streambank stabilization [53].

Figure 5. Existing of large rocks and vegetated riparian areas in the Arhavi River.

Koutalakis et al. (2020) [21] conducted a research to capture and record torrent bed and banks, flood debris, and riparian areas using a small UAV along a reach of Kallifytos torrent in northern Greece. They created orthomosaics using the photos obtained during these drone flights. Their results indicated that after every major flood events, the orthomosaics clearly revealed changes in the torrent bed and indicated debris flow occurrences. Furthermore, the results of the riparian vegetation assessment were satisfactory (Figure 5). They concluded that the use of UAV photographs to capture, record, and monitor fluvio-geomorphological phenomena and riparian vegetation shows considerable promise and their use would aid water managers in developing more long-term management solutions based on real-world data.

Mining activities have a long-term and progressive impact on both land and ecosystem, therefore monitoring is a continual observation and evaluation on the time "axis" rather than a corresponding time "point." Ren et al. (2019) [35] reviewed current status and future perspectives of UAV monitoring in mining areas. They stated that UAVs are effective tools for monitoring and evaluating geological, agricultural, ecological, and forestry growth because of their low cost, short revisiting cycle, flexibility, and high precision.

According to studies, the effective monitoring area of UAVs is between 100 and 100000 m2, with a 2-20 cm inaccuracy [42]. Direct expressions of open-cast and underground mining include pressure, excavation, and terrain collapse. Changes in micro-geomorphology, vegetation, soil, and water systems within the mining activities are other types of land disturbance that have a significant impact on land productivity [14]. A unique symptom of profound land damage is the imbalance of hydrological and geological conditions [15]. The Arhavi River Watershed in Turkey houses many mining and quarry activities. Frequent monitoring of these areas with UAV can help us to detect any pollutant that released to streams and take any measurements to reduce them entering the streams.

5.5.3. Stormwater Control BMPs

Runoff is directed to a sediment trap, pond, or other appropriate stabilized outflow from above exposed slopes or a damaged site. Dikes and swales can be used to provide permanent site drainage control while also transporting temporary development flows. Farmers use perennial swale for reducing stormwater erosion effects (Figure 6). Check Dams reduce velocities in a ditch, dike or swale. Using an UAV, locations of disturbed areas must be investigated before doing any permanent installations (Figure 6).

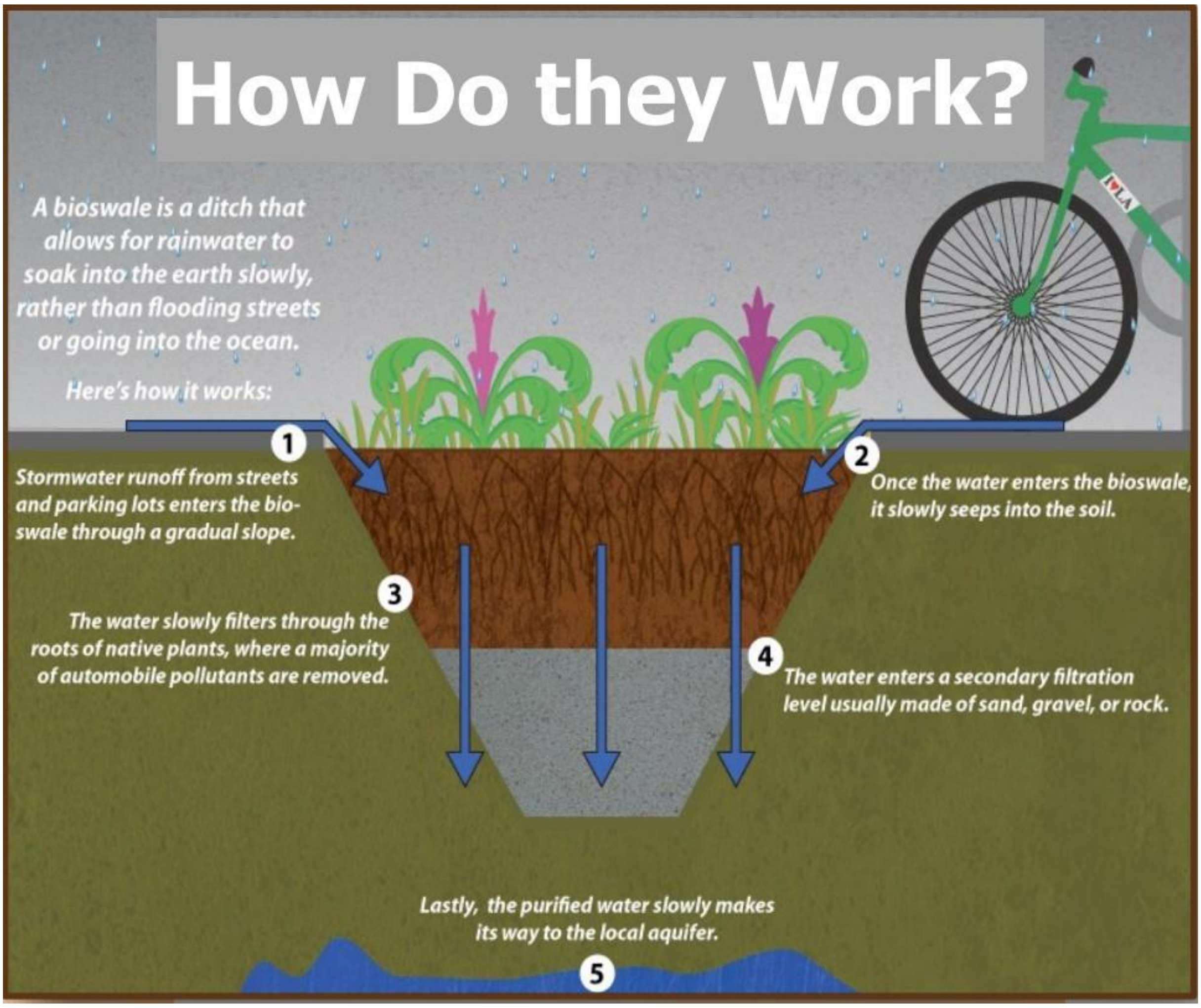

Figure 6. Swales are troughs that collect runoff from the site and filter it through soil, gravel layers, and vegetation, allowing it to slowly percolate into the soil. (Source: [City of Binghamton NY 2016](#))

5.5.4. Stormwater Barriers

Stormwater barriers are a collection of moveable objects such as rock sack berms, foam triangles, plastic dams, hay bales, and other items that are used to hold stormwater and sediment-laden flows back. These systems are frequently man-made, can be modular and hence replaced by portions, and can settle sediment. Flow dissipation is a feature of several systems. Stormwater erosion-laden flows are temporarily ponded. Straw bales are used to divert sediment flow in an emergency. Ponds and Sediment Traps Control the flow of sediment-laden water leaving the site [50]. Collecting and storing eroded sediment from disturbed exposed ground surfaces during construction. Designers should think about whether ponds designed to control sediment and other pollutants during construction could also be utilized to regulate stormwater runoff afterward.

Figure 7. A team from Artvin Coruh University in Turkey uses a small UAV to inspect the stream channel for erosion in an Arhavi River tributary (Photo by M. Yavuz, 2021)

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Protect-Streams-4-Sea

Black Sea CROSS BORDER COOPERATION

Common Borders. Common Solutions

Project title: Black Sea Basin interdisciplinary cooperation network for sustainable joint monitoring of environmental toxicants migration, improved evaluation of ecological state and human health impact of harmful substances, and public exposure prevention

Project acronym: Protect-Streams-4-Sea

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Protect-Streams-4-Sea

Black Sea
CROSS BORDER COOPERATION
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Joint Operational Programme Black Sea Basin 2014-2020

"Black Sea Basin interdisciplinary cooperation network for sustainable joint monitoring of environmental toxicants migration, improved evaluation of ecological state and human health impact of harmful substances, and public exposure prevention"

Protect-Streams-4-Sea Management Team
January 5th 2021

Joint Technical Secretariat of Joint Operational Programme Black Sea Basin 2014-2020

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