Implications of Dedicated Environmental Information Systems in the Firiza Valley Area (Baia Mare, Romania) Characterization to Establish the Dynamics of Pollutant Transfer from Soil to Crop Plants

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Abstract: *We start from the idea that environmental information systems (EISs) - developed under the aegis of environmental informatics (EI) - have been within the reach of specialists and practitioners for more than 3-4 decades, favoring the sustainable development of communities, by making and applying the best possible decisions. From the perspective of soil resource protection and sustainable land management, this paper proposes to analyze the implications of using such information systems in preliminary characterizing an area of specific interest. Through this approach, we aim to draw attention to the facilities we currently have at our disposal - through the mediation of technologies - that prove to be of real use, especially in the characterization and analysis at local, zonal, and regional levels of a site, to subsequently establish the dynamics of the transfer of pollutants from soil to plants. What we have noticed are the multiple possibilities of characterizing an area from the EISs perspective - that have emerged in the last 7-10 years - most of which are intended to emphasize and impose the (re)adaptation of research scenarios and the fight against environmental pollution, and to (re)define opportunities for community development based on sustainable principles. Consequently, it matters not only what we propose to do, but also what each of us can do, with the technology we have at hand; or, in this case, promoting EISs in applied research, in the pollution-affected field, we consider to be a niche of interest that deserves much more attention nowadays.*

Keywords: *Zonal characterization, soil resources protection, environmental information systems*

1. Introduction

According to the Sustainable Development Goals (SDGs) - issued under the auspices of the United Nations (UN) [1] - environmental protection, especially the protection of soil resources, regardless of the area of interest, is one of the greatest challenges of contemporary human society [2]. This challenge addresses politics and economics [3], technology [4-6], informatics, as well as advanced research associated with environmental informatics [7,8]. Under these conditions, the various problems related to environmental protection can be solved very easily by having at hand complex databases, which are also flexible and dynamic [9]. Therefore, public access to data is decisive in the substantiation and decision-making regarding the protection of soil resources, the sustainable management of land, and the risk situations associated with existing pollution at the level of contaminated sites.

In this context, figure 1 highlights how information technology relates to community areas of interest, to provide information, and knowledge that are extremely useful in managing the various problems that inevitably arise from human-environment interaction. The state and dynamics of the environment are described by developing and using biological, physical, chemical, geological, meteorological, and/or socio-economic data sets, that are time and space-dependent [3,7,10].

The processing of environmental data (e.g. *soil stress factors*) and its influence mechanisms are fundamental for any kind of environmental planning and preventive measures. Therefore, solving environmental problems is mainly a processing activity for a wide range of data and appropriate solutions [3,4], specific to each environmental factor [12]. However, solutions to environmental problems depend on and are influenced - to the greatest extent - by the quality of information (re)sources, as it is known that information is a critical factor in initiating political actions and changing attitudes towards the environment.

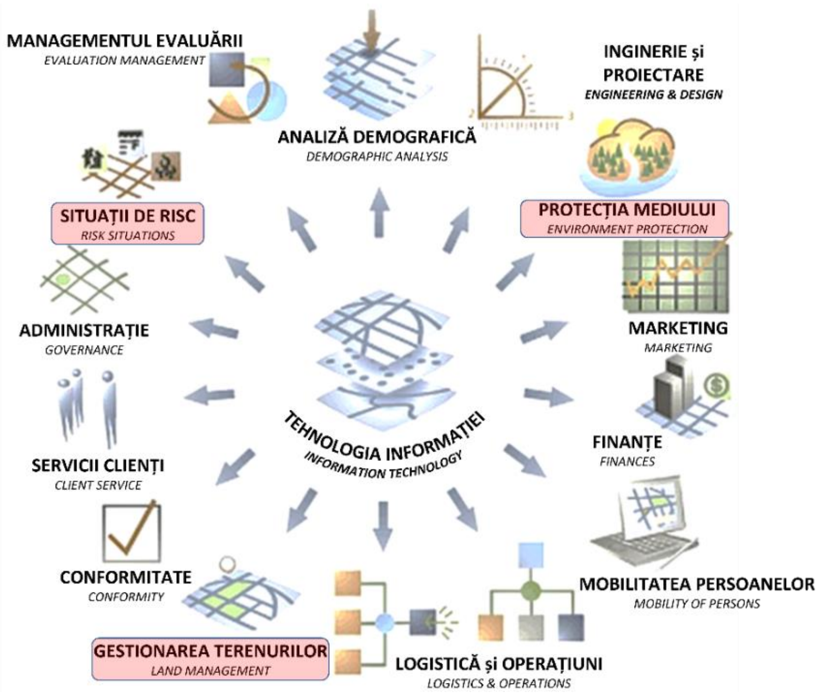

Fig. 1. Current implications of information technology in community activities of interest

Meanwhile, the use of information technology has become essential in the field of environmental protection and engineering, for providing the necessary information at the appropriate level of detail, completeness, accuracy, and speed. This information is equally important as a basis for decisions on actions in the field of environmental protection, as well as for acquiring knowledge in environmental research. Thus, in recent years, environmental information processing systems (EIPSs) have evolved from research and development systems to practical applications.

Currently, many of these systems already support environmental activities at industrial [13], governmental, and global levels [14,15]. At the same time, several trends have been reported regarding the relationship between information technology and the environment, if we refer to aspects such as environmental monitoring through remote sensing and combining global data flows, the policy of sharing and integrating ecological data within political and organizational boundaries, advanced model analysis techniques and industrial applications of environmental information processing [16,17]. However, we cannot fully state that the applications of information technology in the environmental field have often had a solid scientific basis since there has been no significant research oriented toward this topic. This continues to be, certainly, not only a matter related to computer science but also an interdisciplinary task in which several disciplines must be included and involved. On the other hand, regarding the processing of environmental data, this continues to represent a great challenge also for computer science methodologies and their applications, including in the case of dedicated mobile applications, which seem to be coming strongly and more and more visibly behind.

In the sense of the above, it is worth remembering that the application of new information and communication technologies to solve environmental problems began in the 1950s, with the first numerical models used for the management of water and soil resources. Applications followed for atmospheric dispersion models, socio-economic and resource planning models, models for renewable energy production, etc., all require a systematic interdisciplinary methodology [3,4,9].

Environmental data processing systems (EDPSs), including the EISs, play a special role in environmental decision-making, closely related to the demands of society in recent decades. At the same time, EISs constitute a new subfield of applied informatics, which comes up with specific methods and tools for investigating, avoiding, and/or minimizing environmental burdens and damages [2,4]. Later, Page and Rautenstrauch [14] define environmental informatics as a subdiscipline of applied informatics that deals with the development of methods, techniques, and tools for the analysis, support, and establishment of those information processing procedures that contribute to the investigation, avoidance, and minimization of environmental burdens and damages. Thus, for the first time, the emphasis is placed on the mediator role of this discipline, which analyzes real-world problems at length and (re) defines the requirements for environmental data processing, as shown in Figure 2.

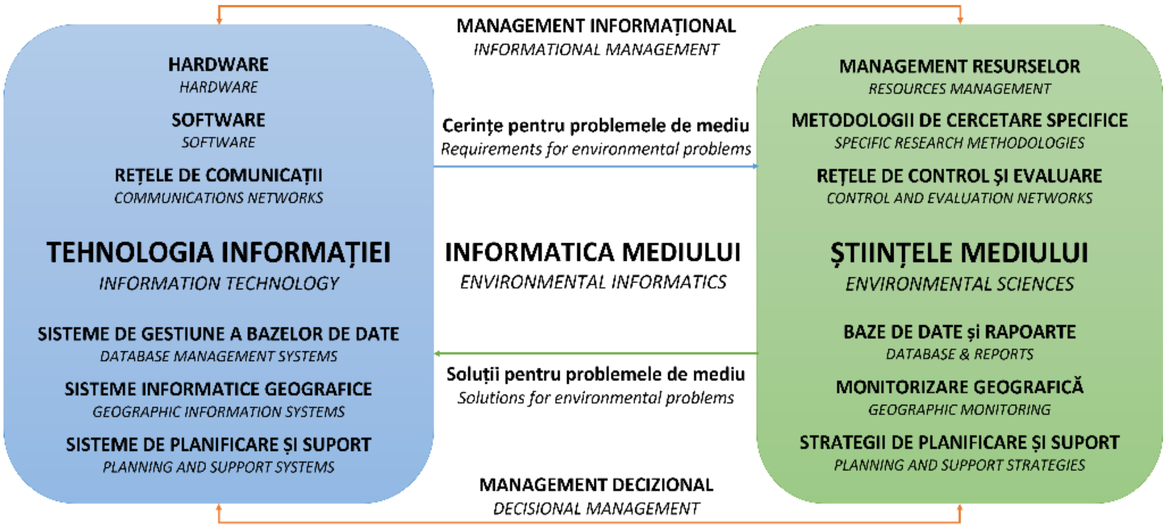

Fig. 2. Environmental Informatics as a bridge between Information Technology and Environmental Sciences

Since the emergence of Environmental Informatics (EI) in the period 1992-1996, EISs have constantly changed; the boundaries of EISs have expanded, so that industrial processes causing significant energy consumption and emissions have increasingly come into the spotlight. The focus has shifted from effects to causes, and implicitly from environmental impact to processes that can be modified to minimize it. For this reason, methods for simulating industrial production processes must be integrated with approaches to the analysis of information flows.

In these circumstances, we conclude, from the current field practice, that the conceptual models that underlie the definition of EI, respectively the integration of EISs in the community development strategy, start from the acquisition, processing, and use of environmental information and end with the support of decision-making. To explain the existing links between the information environment, society, and the environment, the entire process of acquiring and processing environmental data must be done starting from the ecological problem analysis scheme, with an emphasis on pressure-state response. The public has access to environmental information and can thus make the best decisions concerning the activities they carry out, especially by consulting specific learning communities; moreover, it can elegantly ensure the sustainable development of the community.

As for the impacts that may affect the soil, these can be managed in time and space. Through computational reasoning, mathematical modeling and simulation, fine-grained monitoring, etc., data on soil quality status can be understood and interpreted correctly, allowing for correct and efficient decision-making. Following the same work plan, after 2020, substantial progress has been made to achieve a broader appreciation of the soil's key role, according to the ecosystem services it provides. Science is advancing, with an improved understanding of the fundamental mechanisms that control the dynamics of the qualitative state of soil parameters, as well as in the measurement and modeling of changes, in response to environmental and management factors. As a result of this progress, entrepreneurial programs, and methods have been and are being developed that contribute to paving the way for a better inclusion of soil management in the decision-making process of farmers and livestock breeders.

2. Material and methods - the perspective addressed by current research

However, to move towards aggressive implementation of best land use and management practices to promote global soil health, a new soil information system, with global coverage and the capacity to evolve as science advances, is needed. While the data and many of the necessary tools, technologies, and collaborations exist, the information is often fragmented and its availability is limited. Better coordination, transparency, and accessibility of tools and data between specialists and land managers is needed.

In addition, to understand the specifics of the relationship between EISs users and specific learning communities, in Fig. 3 we have chosen to illustrate a virtual platform for quantifying the data model needed to form the core of a new soil information system. Starting from the left side of the diagram, key data sources are presented to inform and validate soil protection estimates. The usefulness of data from experiments, both in the field and over the long term, helps to formulate, parameterize, and validate predictive models of soil changes.

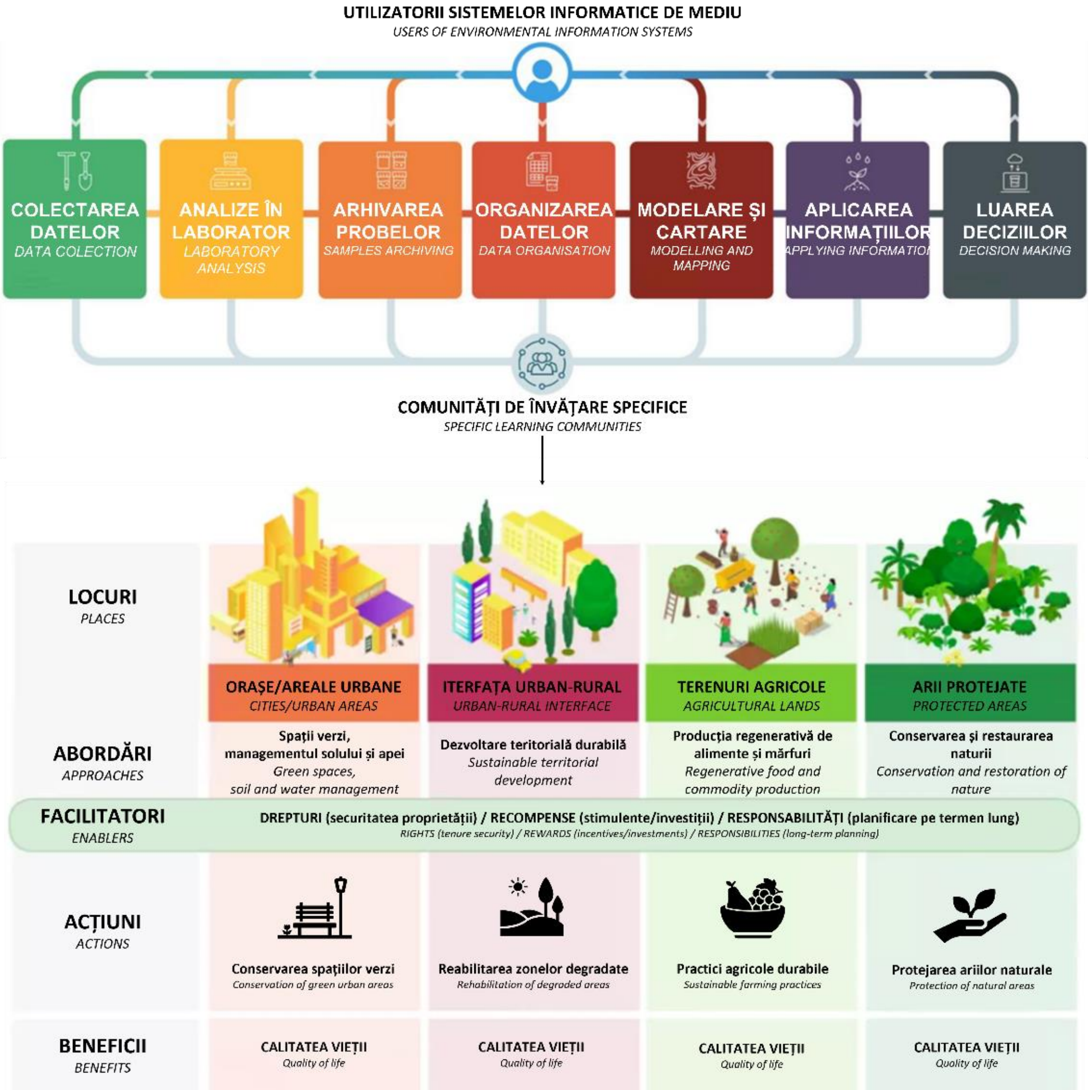

Fig. 3. Information flow from data collection to decision-making and consultation of specific learning communities

Soil monitoring networks can play a vital role in reducing the uncertainty of models provided by mobile applications. However, such monitoring networks are lacking in most countries and, where data exist, they are not easily accessible to the community. Developing data-sharing agreements could pave the way for a consolidated global soil monitoring network, the accessibility and usefulness of which could stimulate other interested entities to join this effort. Such a platform would support and facilitate the use of innovative approaches, with a focus on the protection of soil resources and sustainable land use, with a focus on reducing CO_2 emissions from the atmosphere and sequestering carbon in the soil.

Model ensembles are driven by spatially generated and modeled datasets (see Fig. 4), including climate variables (e.g., *temperature*, *precipitation*, *solar radiation*), soil conditions (e.g., *soil texture*, *mineralogy*, *soil profile depth*, *topographic features*), and land use, as well as management data (e.g., *crop rotation*, *nutrient management*). Provided that the models used are generalizable over a sufficiently wide range of environmental conditions, the scale of inference for predicted variables is largely determined by the spatial resolution of the input data, which can be obtained both by remote sensing and by mobile applications directly in the field. Remote sensing, as well as mobile applications, offers the potential to provide low-cost, small-scale, and globally available data on land cover and crop species, as well as data on soil cultivation and irrigation practices, which can assist the user in making the right decisions.

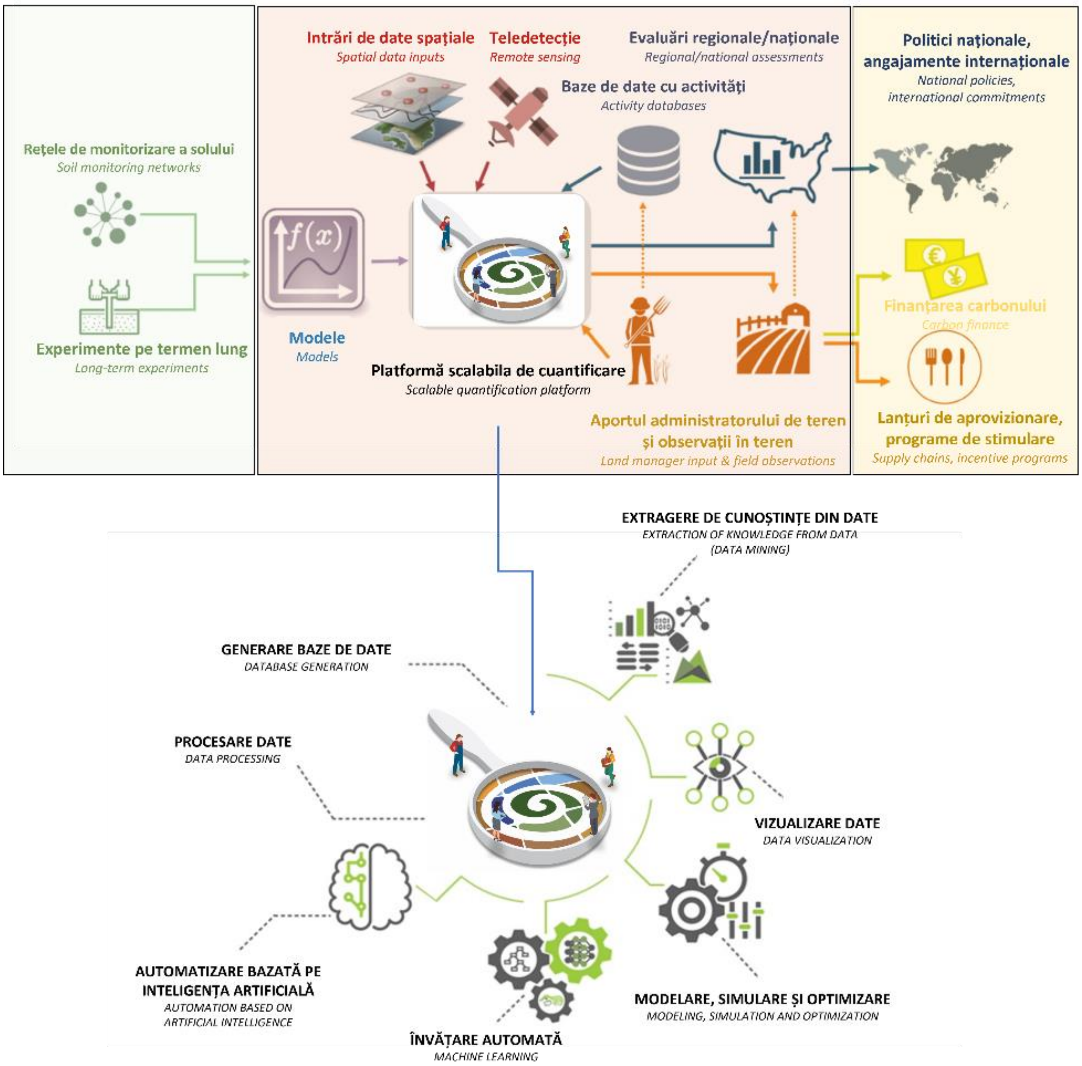

Fig. 4. The range of IT tools used to understand soil protection issues (after PAUSTIAN et. al, 2019)

Therefore, there is a need to test promising methods on a larger scale and then develop capabilities that can rapidly provide data on management practices at high spatial resolution, anywhere in the world. Dynamic models supported by experimental mobile applications based on spatially distributed soil, climate, and management data can support land managers' decisions. A scalable system, capable of country-level analysis, will be needed to support national policies and international agreements, to support sustainable supply chain initiatives and/or financing schemes that can incentivize farmers to adopt sustainable practices for land use and current technology use.

From the perspective of environmental engineering and protection specialists, it is well known that the assessment of the dynamics, specificity, and intensity of pollution in a given contaminated site is usually carried out by comparison with the natural background (reference) in adjacent areas - with values established according to the area and the existing geological formation - and with the alert threshold and intervention threshold values provided for in specific regulations.
A contaminated site, as defined by the European Commission reports, represents a confirmed and well-demarcated area that represents a potential risk to humans, animals, and the environment. The number of contaminated sites at the international and national levels has been high in the past and has continued to grow in many areas [18], where certain specific measures have not been considered and applied. At the international level, numerous studies and research have been carried out to find the best treatment methods, when preventing the contamination of a site has not been possible. Numerous methods, more or less viable from an economic and ecological point of view, have been considered. These methods include *thermal treatment*, *electrochemical treatment*, *bioremediation*, *dechlorination*, *thermal desorption*, *washing*, *solvent extraction*, etc. All these methods were applied according to the needs, taking into account various other factors.
For the present research, we established as the investigation perimeter an area in the Firiza Valley area, taking into account the fact that the geomorphological and climatic particularities of the area are relatively similar to those in the urban area of Baia Mare (Romania). In the reference area (Firiza Valley - Baia Mare, Romania), as well as globally, one of the most polluted resources is soil. This resource has been and is polluted as a result of industrial activities such as mining, but also the storage and use of associated products. Under these conditions, if certain hazardous substances are not used appropriately and subsequently not stored or eliminated as required by law, the soil can become contaminated, and people can be exposed to soil contaminants through various routes, especially from contaminated soil to crop plants.

3. Results and discussions. Firiza Valley - a brief characterization of the area via EISs

The Baia Mare administrative-territorial unit includes the upper basin of the Firiza Valley, on the right slope, from Valea Pistruia-Blidar upstream, and on the left slope, from Valea Jidovoaia upstream. The highest peaks are located on the ridges that delimit the basin to the west, north, and then east: Calamari peak (1141 m), Ogorohii peak - Dealul Miculi (1191 m), Rotunda peak (1240 m), Stânilor peak (1152 m), Pleşca Mare peak (1294 m), Breze peak (1254 m) and Igniş peak (1307 m).

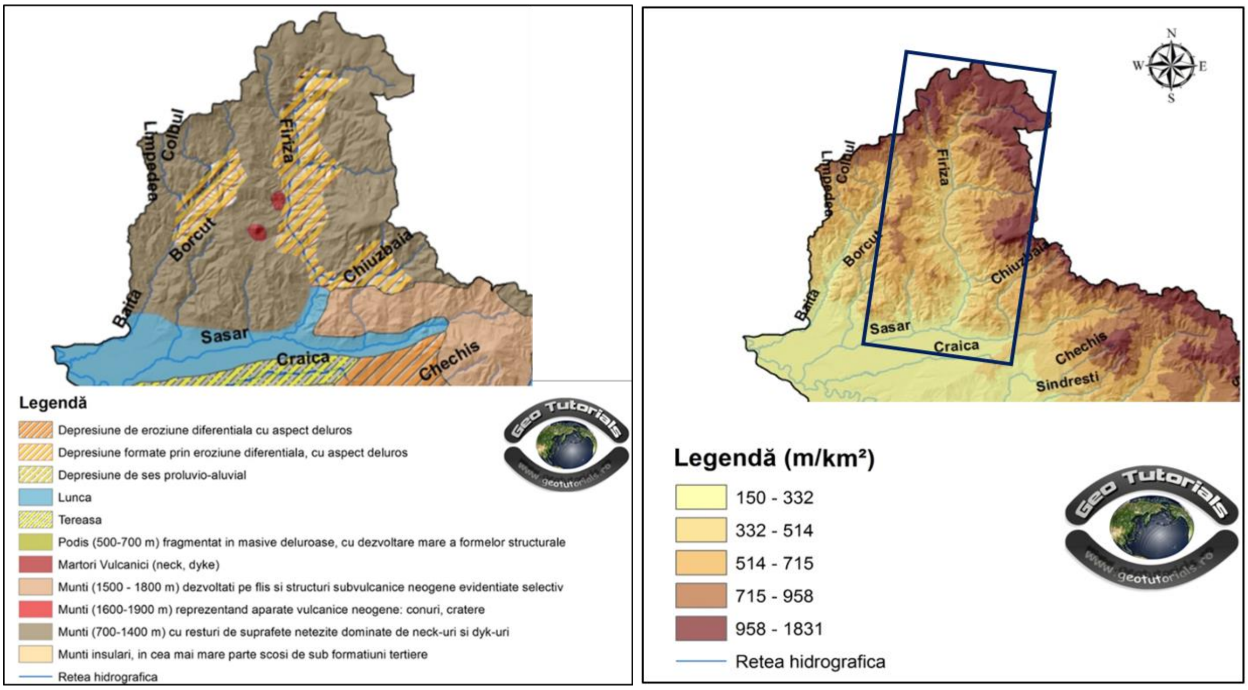

Fig. 5. Geomorphological map of the Firiza Valley (Baia Mare, Romania)

Two depression basins are outlined in the Firiza Valley: Blidar and Firiza (see Fig. 5). The two depression basins have an eruptive geological substrate and were formed by erosion, at the confluence of the Firiza with the most important tributaries Pistruia and Valea Vrivei at Blidari, Valea Neagră, Valea Roşie, Valea Seicina at Firiza. Moreover, in the existing geomorphological complex of the Firiza Valley, slopes with different inclinations and exposures dominate, In small areas other relief forms are also encountered, such as meadows, plateaus, ridges, and glacis, all of which determine changes in the climatic and edaphic regime and the distribution of vegetation.
The numerous streams (the vast majority of them tributaries of the Firiza River) flowing in a north-south direction, small depressions (Chiuzbaia, Firiza, Blidari) as well as marginal depressions that arose through the regressive erosion of rivers with a base level in the Baia Mare Depression such as Ferneziu, strongly fragment the southern flank of these mountains. In terms of altitude, the base level of the Firiza Valley micro-depression is between 150-715 m, with the relief energy gradually decreasing to 150 m within the meadows. Under these conditions, the declivity of the relief represents a morphometric indicator, frequently used in the complex characterization of the relief.

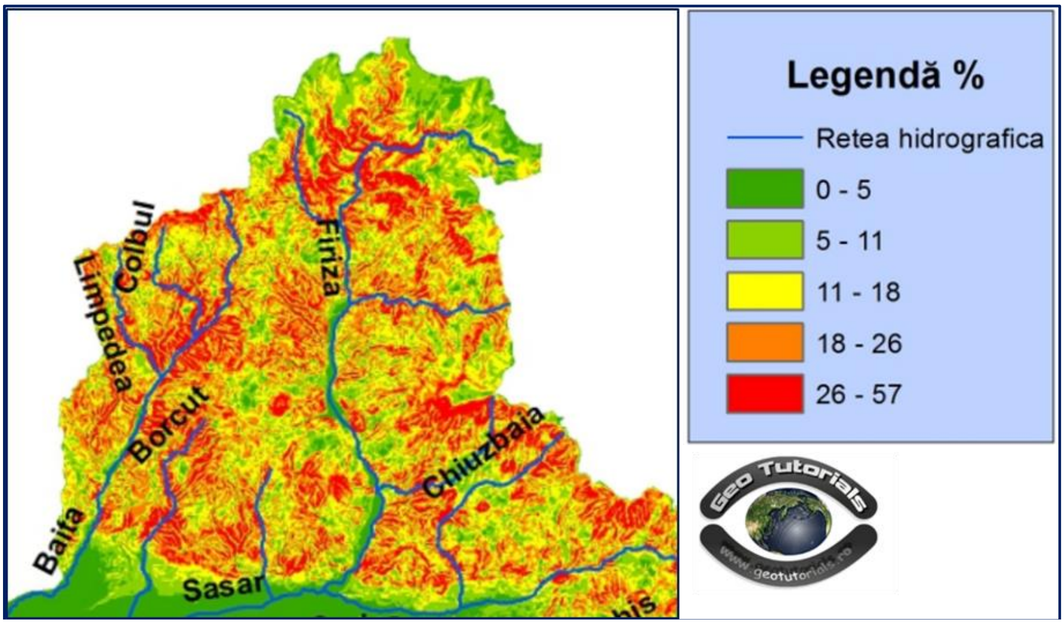

Fig. 6. Slope map of the Firiza Valley (Baia Mare, Romania)

The slope of the relief conditions, together with geological (petrography and structure), climatic, hydrological, biopedogeographic, and anthropogenic factors, the genesis, dynamics, intensity, and type of denudation processes. In the Firiza Valley basin, the high values of slopes between 26% and 57% are given by the slopes of the mountain massifs (see Fig. 6), this fact makes the drainage of the tributaries take place from N to S. The average values between 5% and 26% are found in depressions, hills and peaks and the lowest values are recorded in the river meadow.
The Firiza River basin is the most important tributary of the Săsar, with a river basin that drains a significant part of the mountainous area of the Baia Mare administrative-territorial unit. The Firiza River basin has an area of 168.6 km^2 and a length of 28 km, the springs being located at an altitude of 1050-1070 m. The average altitude (744 m) is almost 100 m higher than that of the Săsar river basin upstream of the confluence with the Firiza, and the average slope is 10 m higher.
On the Firiza river, at approx. 10 km away from the city center, the Strâmtori dam (52 m high) was built, creating a reservoir with an area of 110 ha, which represents the only source of water supply for the Municipality of Baia Mare. Taking into account the characteristics of the Firiza hydrographic basin upstream of the lake, it plays a decisive role in protecting Baia Mare against floods. Construction works took place between 1961 and 1964, and in 1964 the lake was put into operation. Until now, the Firiza Valley has not been the subject of detailed topoclimatic research, with studies focusing on the design and construction of tall dispersion chimneys on the structure's resistance to maximum wind force and on compliance with the maximum permissible concentrations of pollutants in the ambient air.

The climatic characteristics in the Firiza Valley area are approximately the same as those in the Baia Mare area [19], thus we can state that:

- The particularities of the thermal regime in the Firiza Valley micro-depression are also reflected in the distribution of days with different thermal characteristics, which have an obvious altitudinal zonality, with a relatively large number of frost-free days (on average over 183-185 days, maximum 227); rarely, late spring frosts lead to the thawing of seedlings that started vegetation earlier, of newly formed vines (e.g., for beech and maple) or walnut, cherry and ash leaves;
- The relative humidity of the air (by combining water vapor with atmospheric precipitation) gives the climate - through its high values, especially in the spring months (87-88%) - the character of "humid", creating the humidity environment indispensable for life (see Fig. 7);
- cloudiness - a reliable indicator of the thermodynamic processes in their area of existence and of the precipitation - in some places more difficult to notice, is in direct correlation with the heavy (background) precipitation and with the low wind intensities, moreover, the maximum for atmospheric calm and fog is also recorded;
- atmospheric precipitation presents a great variability in time and space (in terms of frequency, intensity, and duration), the highest values are recorded on the southern slopes of the Oaş-Gutâi-Ţibleş mountain range (873.0 mm at Baia Mare);
- data regarding the duration of days of the ground covered with snow show us that the first snowfalls usually fall at the end of November, while the last snowfalls are delayed, being recorded at the end of April, or even in mid-May (18 cm in the Firiza valley, compared to that from the outside of the depression);

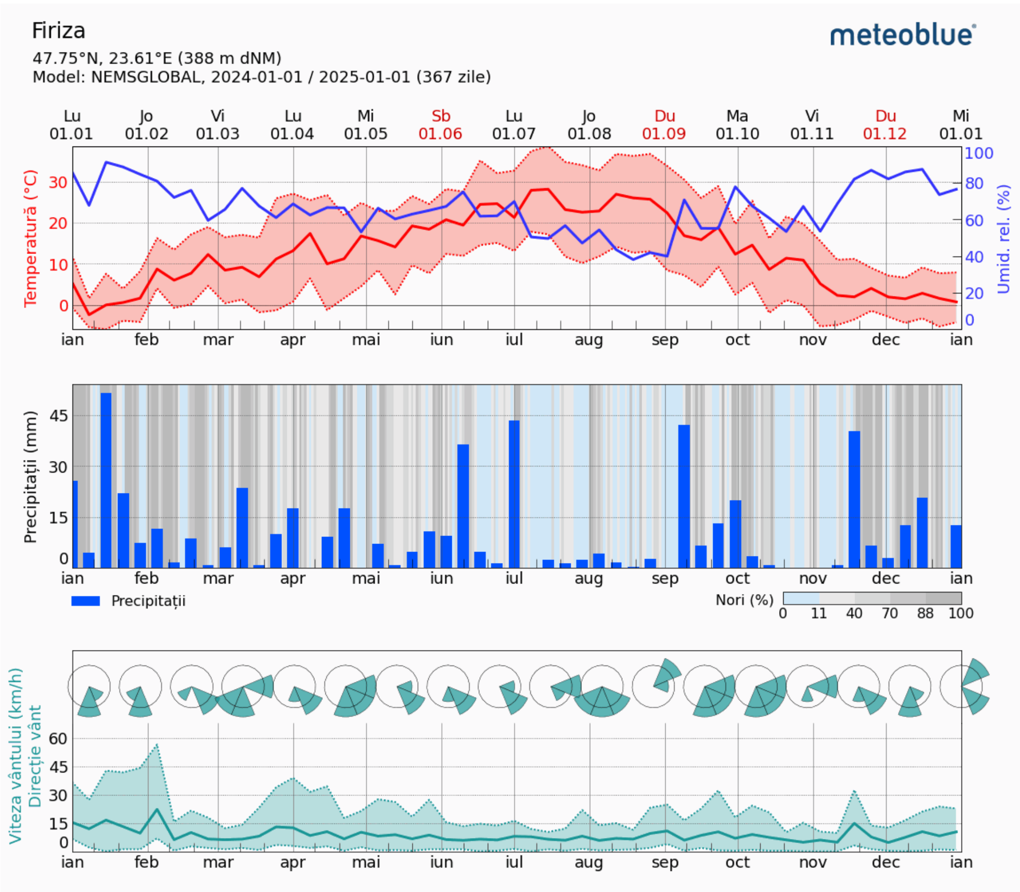

Fig. 7. Meteorological archive containing data on temperature variation, relative humidity, precipitation, cloudiness, wind speed, and direction for Firiza Valley areal, 2024 (www.meteoblue.com) [20]

- The atmospheric calm has an annual average value of 51.2%, so the area is generally weakly windy, while the maximum is recorded in winter (61.9% in January), and the minimum in spring (41.1% in April);

- The annual average wind speeds are low (2.2-3.6 m/s), and the direction in which the wind has minimum values is south (1.8 m/s in January and February), while the directions in which the wind has maximum values are west and northwest (up to 4.5 m/s); these low values associated with the values of atmospheric calm show that in the reference area, the natural dispersal capacity is low.

Regarding the surplus and deficit of soil water, due to the large amounts of precipitation in the Firiza Valley area, there is no deficit of soil water, the soil water regime being alternating percolative in the depressional plain and deep percolative in the hill and pre-mountain areas. In terms of the water regime, the soils are favorable for the development of forest vegetation.

The main types of soils in the researched area are visibly linked and conditioned by the two large relief units, namely the Gutâi Mountains and the Baia Mare Depression. These are presented - under the influence of the main pedoclimatic factors - in two large categories, namely:

- soils of mountain areas - appear on the southern slopes of the Gutâi Mountains and have as their main characteristic the presence of the skeleton and the small thickness of the soil profile; this category includes: undeveloped soils (lithosols) formed on consolidated rocks, andosols in association with brown podzolic soils formed on volcanic rocks, brown-acid soils formed on andesitic volcanic rocks, and eroded brown (eubasic) soils and regosols.
- soils of depression areas - occur in the Baia Mare urban area and on the hills located south of it; the main types of soils in this category are: pseudogleyed and pseudogleyed podzolic soils formed on slightly sloping, poorly drained lands, brown clayey-iluvial soils, the type of brown soils (including podzolites), brown podzolic soils and eroded brown podzolic soils, and amphigleyic podzolic and alluvial soils, along with other soils with a visible and pronounced anthropic character.

Moreover, from a pedological point of view, in the experimental perimeters of the targeted area (Firiza Valley), we encountered representative soils from the luvisols and hydrosols classes, whose use was predominantly agricultural (with and without current crops and/or plowing).

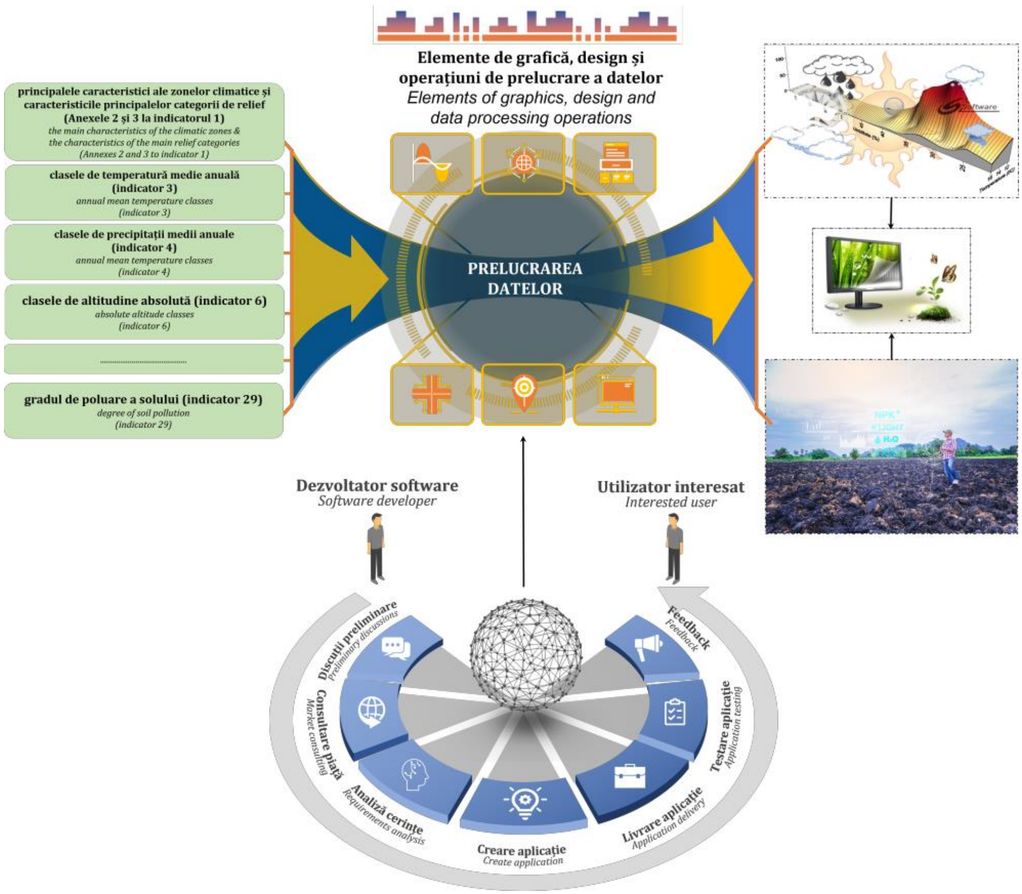

Fig. 8. Selection of eco-pedological indicators as a defining element in the characterization of an area of interest through the facilities offered by the mobile dedicated EISs used

At the same time, it is worth mentioning that in the respective locations, all the characteristics that we found at the level of thematic maps (e.g., relief, climate, spontaneous vegetation, land use) via mobile dedicated EISs (Fig. 8) are fully met, which only confirms that the situation in the reports and maps corresponds to reality. Regarding the current state of knowledge of soil quality and implicitly of current land use, to establish the dynamics of the transfer of pollutants from the soil to crop plants (for inhabited areas), by using mobile applications dedicated to soil protection, it is noteworthy, according to TOOR et al. (2021), an emphasis on the use of technology after 2020, in combination with high-throughput analysis methods (Fig. 9) and new types of analyses based on precision sensors.

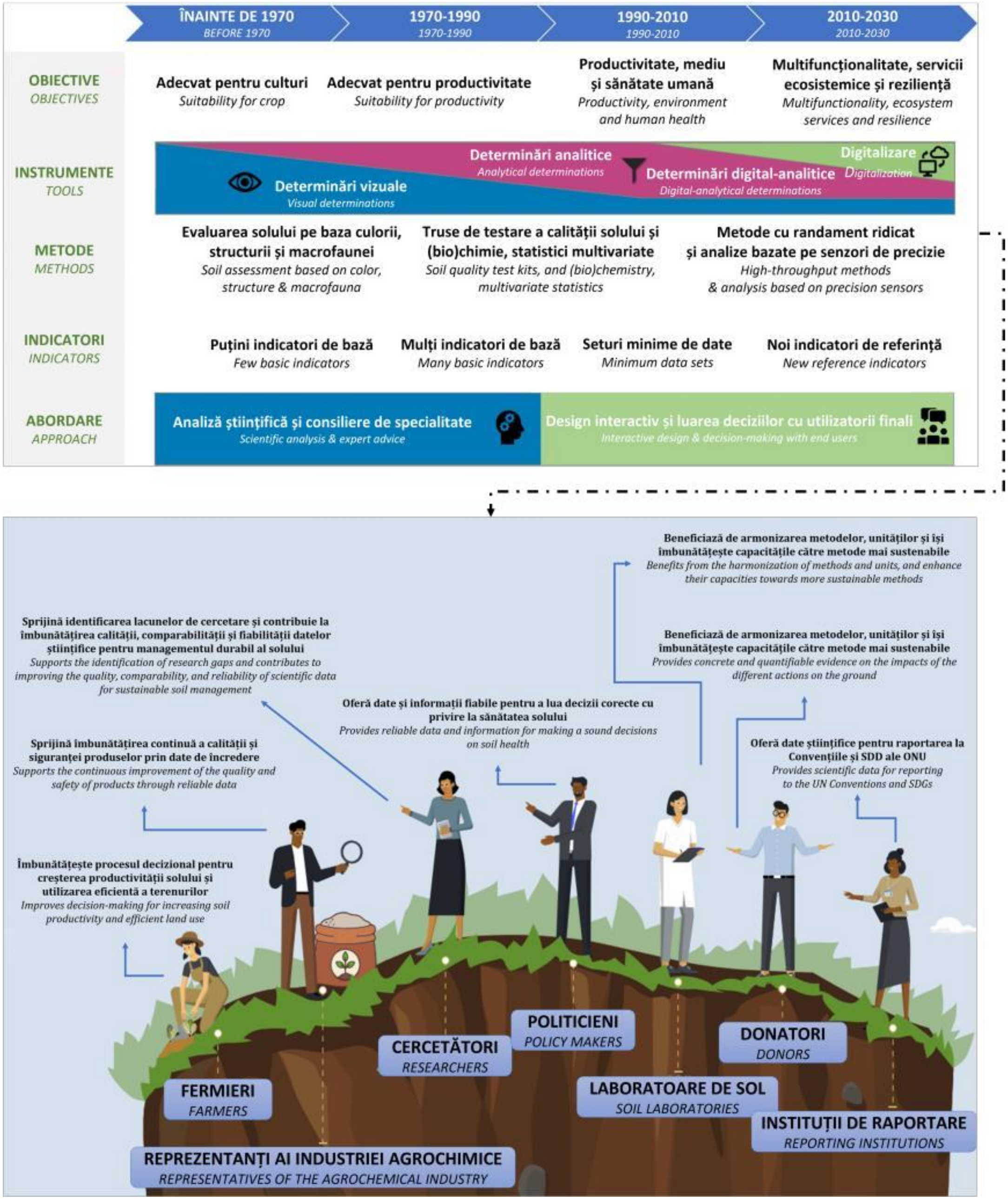

Fig. 9. Current status of the use of modern technologies in soil protection, including for the reference area - Firiza Valley [21]

In the same context, figure 7 shows a gradual shift from objectives that consider soil as suitable for crops (before 1970) and productivity (1970-1990) to those that emphasize soil multifunctionality and ecosystem services. At the same time, it is also noted the need to approach soil protection with new reference indicators that can support the effort made by farmers, researchers, representatives of various institutions with concerns in the field, etc., who increasingly use digital monitoring and control tools. The use of mobile applications dedicated exclusively to the protection of soil resources has as an extension the generation of empirical models, reports, and maps, the aim is to ensure that authorities, the business environment, and the interested public have access to relevant data and information, approach that is synthetically represented in Fig. 10.

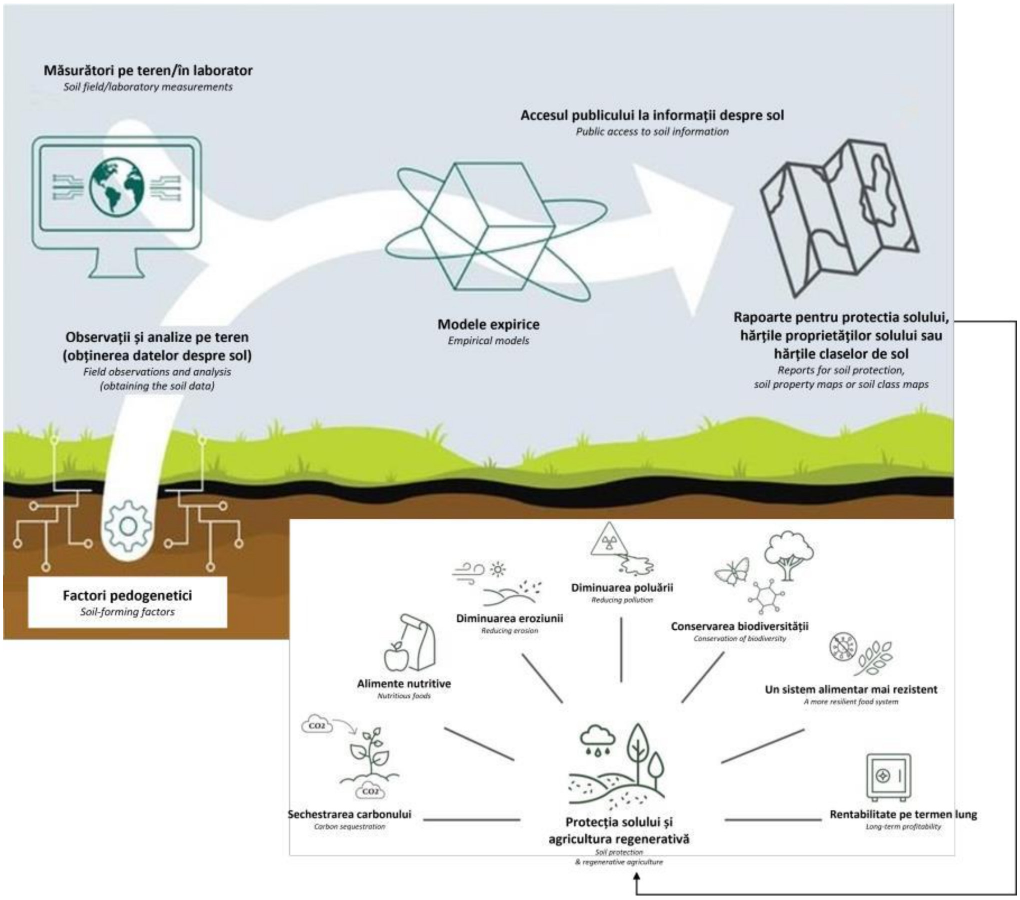

Fig. 10. Soil protection about the 7 benefits of regenerative agriculture

Such an approach also has implications for regenerative and precision agriculture, where we find a significant series of benefits. Starting with carbon sequestration and the provision of nutritious and good quality food, regenerative agriculture as a result of soil protection leads to biodiversity conservation and, implicitly, to long-term economic profitability.

4. Conclusions, perspectives, and proposals

Sustainable development as a concept seeks and tries to find a stable theoretical framework for decision-making in any situation where a human-environment relationship is found, whether it is the environment, the economic environment, or the social environment. Although initially sustainable development was intended to be a solution to the ecological crisis caused by the intense industrial exploitation of resources and the continuous degradation of the environment and sought to preserve the quality of the environment, currently the concept has expanded to the quality of life in its complexity, also from an economic and social perspective.

Soil monitoring and protection - especially in areas where communities have carried out various activities with a pronounced polluting nature over time - as well as field activities carried out by specialists or personnel with concerns in the field, are elements that require an integrated approach, from which the mobile technological component cannot be missing. At the same time, the incursion of these approaches (especially in the preliminary research activity, in the field, for a reference area, such as the one considered) must be carried out with equipment that allows more efficient control in the acquisition, processing, storage/saving, and dissemination of data.

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