EO Clinic project:

Estimating Irrigation Potential in Romania

Work Order Report

Support requested by:
World Bank Group (WBG)

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[RD-1]	ESA Request for Proposal: EOC0018_RFP_v02
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[RD-3]	Financial Proposal: EOC0018_PRO_C_F_V1 by TERRASIGNA and GeoVille Gmbh

ABOUT THIS DOCUMENT

This publication was prepared in the framework of the EO Clinic (Earth Observation Clinic, see below), in partnership between ESA (European Space Agency), the World Bank Group (WBG) and team of service providers contracted by ESA: TERRASIGNA (Romania) and GeoVille GmbH (Austria) for the management part.

This Work Order Report (WOR) describes the context of the World Bank Group (WBG) activities on irrigation in Romania, the geoinformation requirements of the activities and finally, the EO products and services delivered by the EO Clinic service providers in support of those activities.

This Work Order Report (WOR) is structured as in the following:

- **Section 1** describes the context of the World Bank Group (WBG) activities on estimating irrigation potential in Romania, as well as the project objectives.
- **Section 2** highlights the applied work logic and methodologies followed.
- **Section 3** describes the services, their specifications and outputs.
- **Section 4** presents an evaluation of the data availability and suitability in support of the EO products and services under the perspective of a potential roll-out.

ABOUT THE EO CLINIC

The EO Clinic (Earth Observation Clinic) is an ESA (European Space Agency) initiative to create a rapid-response mechanism for small-scale and exploratory uses of satellite EO information in support of a wide range of International Development projects and activities. The EO Clinic consists of "on-call" technically pre-qualified teams of EO service suppliers and satellite remote sensing experts in ESA member states. These teams are ready to demonstrate the utility of satellite data for the development sector, using their wide range of geospatial data skills and experience with a large variety of satellite data types.

The support teams are ready to meet the short delivery timescales often required by the development sector, targeting a maximum of 3 months from request to solution.

The EO Clinic is also an opportunity to explore more innovative EO products related to developing or improving methodologies for deriving socio-economic and environmental parameters and indicators.

The EO Clinic was launched in March 2019 and is open to support requests by key development banks and agencies during the 2 years project duration.

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1 DEVELOPMENT CONTEXT AND BACKGROUND

1.1 Irrigation in Romania

Rural development is a term that is used in almost all discussions related to agriculture today in Europe and Romania. The modernization of irrigation systems, roads, processing facilities and other related areas are an essential part of making agriculture a profitable and desirable activity, representing the focus of the entire second pillar of the Common Agricultural Policy (CAP).

The Romanian agriculture is facing simultaneous challenges. Firstly, it has to deal with the legacy of the socialist regime and previous approaches that were not always adequate to the local conditions in terms of relief and climate. Secondly, the abrupt decline of the centralized irrigation systems left the agriculture weather-dependent. And finally, the current climate change trends such as drought or flash floods are continuously increasing the water resources risk and urgently require mitigation actions (EEA, 2009).

Considering uniform conditions in terms of soil, slope, hydrogeological conditions, water sources, energy consumption or socio-economic conditions, Romania's theoretical irrigable potential is estimated at about 7.4 million hectares (MARD, 2016). However, on about 2 million hectares, the infrastructure development would require very high investments, economically unjustifiable in the long run. Currently, Romania has an area designed for irrigation of about 3.1 million ha (INSSE, 2019), the largest among all Central and Eastern European countries. However, it is not entirely economically viable, as the area actually irrigated varies greatly from year to year depending on rainfall and the technical condition of the facilities (Fig. 1).

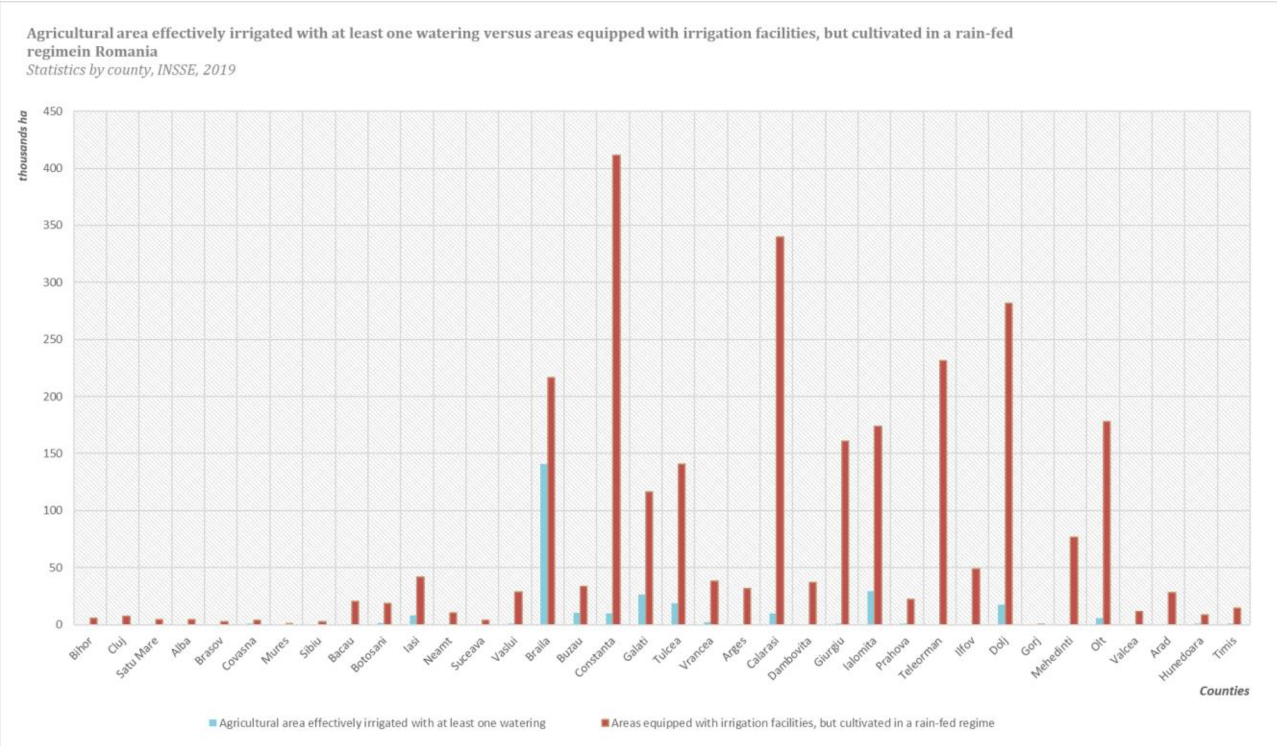


FIGURE 1: Effective use of the existing irrigation systems. Agricultural areas irrigated with at least one watering (2019) versus areas equipped with irrigation facilities, but cultivated in a rain-fed regime (2019)

The existing irrigation infrastructure in Romania is mostly out-dated in terms of resource efficiency. Irrigation systems in Romania were built until 1990, being located mainly in the south, southeast and east of the country, the areas most affected by drought. Major structural reforms over the last two decades have led to extreme farm fragmentation, a transition to full cost recovery tariffs and a sharp drop in the irrigation demand (according to ANIF, 2021, irrigation water volume decreased eight times since 1990). Currently, the irrigation facilities are in an advanced stage of degradation and on more than 75% of the equipped surface, the systems are not functional (ANIF, 2021) or have proven to be inefficient in terms of water and energy consumption and expensive for farmers. The risk of abandonment of the existing irrigation infrastructure facilities is increasing the areas' vulnerability, threatening to generate serious social, economic and environmental problems. Moreover, the increase in the frequency of drought phenomena in recent years (IPCC, 2019) has generated an increase in subsidies / compensation required by farmers (MARD, 2020), thus contributing to the generalized instability of the agricultural areas in question.

Furthermore, the lack of a clear vision, a clear legislative framework in the field of irrigation and the lack of dedicated geospatial databases impede the proper managing of water resources and contribute to increased economic losses.

The irrigation problem in Romania requires economically viable, but also nature-friendly, sustainable solutions (World Bank, 2018), framed in the context of the European Green Deal, the new European strategies \`From Farm to Fork\` and \`Biodiversty 2030\` and of the Common Agricultural Policies (CAP) (Ossewaarde and Ossewaarde-Lowtoo, 2020; European Commission, 2017). There is an urgent need for adapted products and their harmonization the CAP and the objectives of the Commission Strategies. In this regard, Regulation (EU) 2020/2220 of The European Parliament and of the Council of 23 December 2020 aims to provide Member States the time and framework to prepare their Strategic Plans, by establishing a 2-years transition period and extending the applicability of the current Rural Development Plans (RDP). A good management and speculation of this situation, together with the opportunities brought by the National Resilience and Economic Recovery Program (MARD, 2021) represent the chance for rethinking the irrigable areas potential in Romania and compiling a strategic vision for irrigation at national-scale level, promising to provide future stability and certainty for the farming sector in terms of water demands, vital to guarantee food security conditions.

1.2 Objectives

Within the last decade, the World Bank has funded numerous development projects in Romania, totalling several billion dollars, aiming to improve agricultural and forestry productivity. WB has been closely collaborating with the institutions involved in the management of agricultural areas, including rural development and poverty reduction programs, improving rural infrastructure, including irrigation systems, social services and the rural financing system.

The aim of the current service is to map and estimate the potential and suitability of selected areas of interest for the implementation of irrigation projects.

The subordinated objectives are:

- To identify and map the latest status regarding irrigated crops (2019) within three selected areas of interest;
- To derive a set of indicators / decision markers related to vulnerability in relationship to climate change factors versus irrigation potential and integrate them into a multi-criteria assessment analysis;
- To identify the critical / most vulnerable areas in terms of water demand / irrigation needs;
- To establish and rank the areas characterized by the highest potential/suitability for the implementation of improved solutions for water storage and irrigation.

The initial set of information products and insights generated within this activity shall be used mainly by WBG and MARD, as they represent a first step towards a nationwide scaling of the irrigation potential quantification.

As the implementation time dedicated to the pilot was extremely short (less than 4 weeks), the exercise was based only on freely available data sets and processing algorithms that can be implemented using open-source software.

2 PROPOSED WORK LOGIC FOR EO-BASED SOLUTIONS

For the estimation of irrigation potential, TERRASIGNA proposed a complex analysis methodology, structured on 4 levels, respectively 14 tasks, based on specific Earth Observation processing techniques, GIS techniques and algorithms and a multi-criteria analysis. The 4 levels are represented by:

- Data collection;
- Data processing and analysis;
- Stakeholders interactions;
- Quality control and delivery.

The 14 proposed tasks are expressed, depending on the level to which they belong, in Fig. 2.

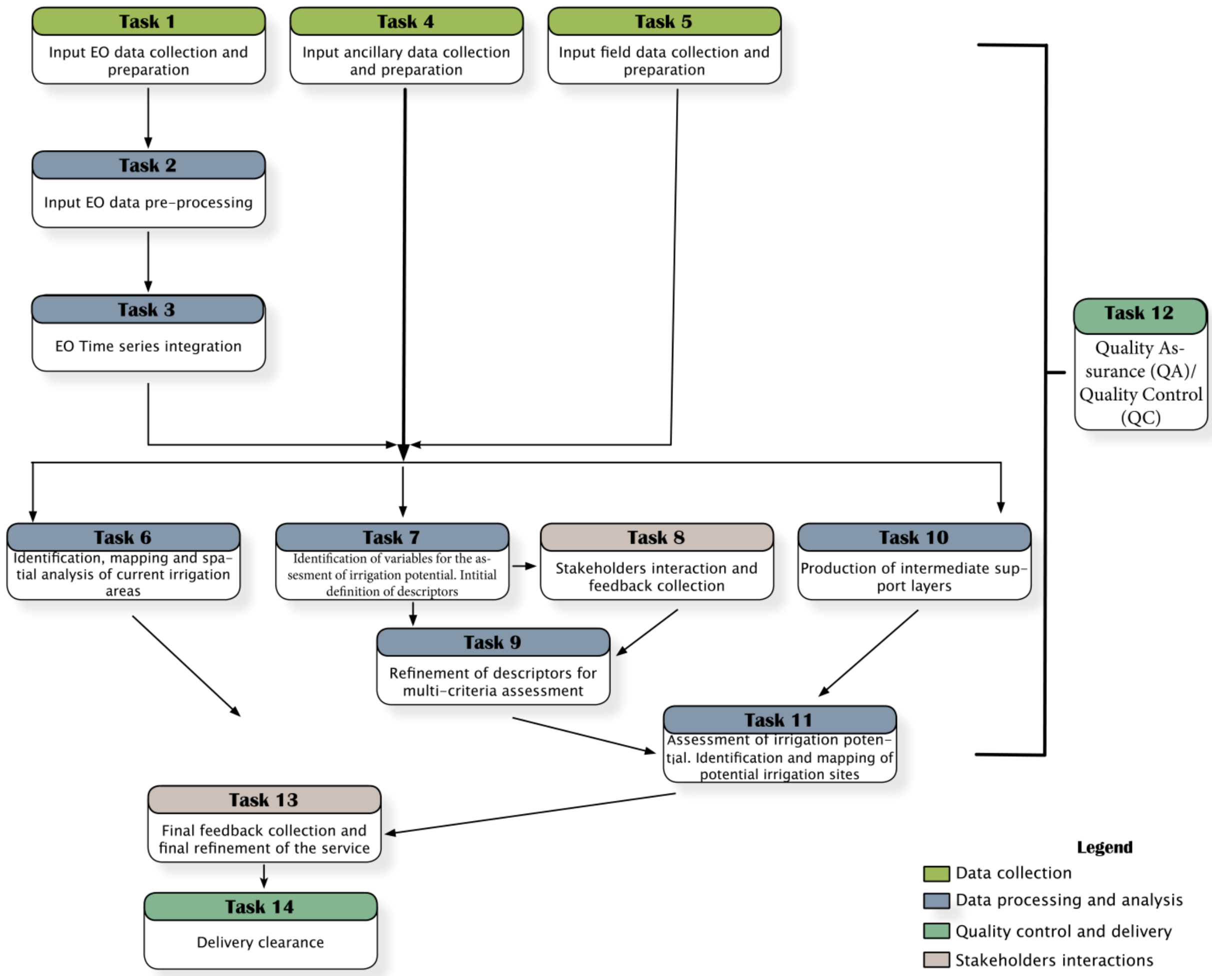


FIGURE 2: Proposed tasks and workflow

The service was implemented by TERRASIGNA and has been planned over a tight period, with a Work Completion Deadline (WCD) of 4 weeks from the issuing of the Work Order (WO). The time plan for implementing the work order was as follows (Fig. 3):

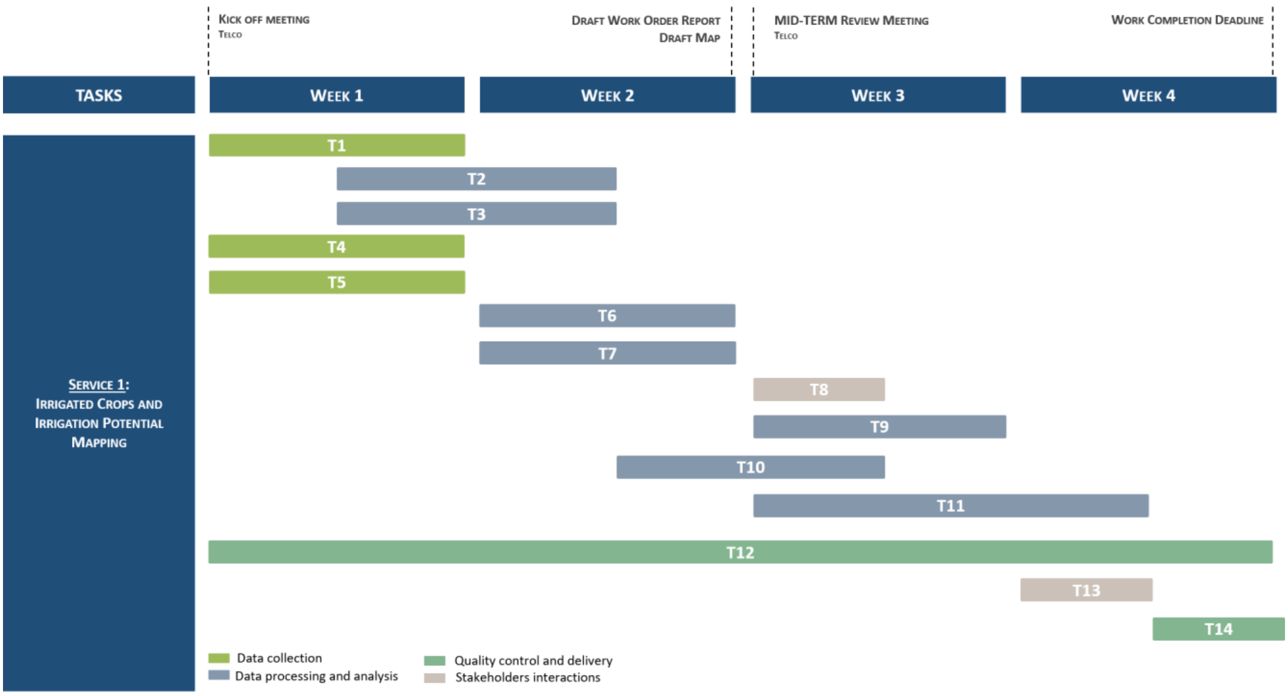


FIGURE 3: Time plan for work implementation

Based on the outputs provided, the service can be split in two main subservices:

- Mapping of Irrigated Areas;
- Quantifying Irrigation Suitability, through a Multi-Criteria Assessment Analysis.

2.1 Mapping of Irrigated Areas

2.1.1 Data inputs

For the crop type mapping and mapping of irrigated areas, the input data consisted in:

- Time series of Sentinel-2 optical satellite data (complemented by Landsat-8 satellite data for the computation of crop type maps);
- Farmers' declarations regarding cultivated crops and areas covered;
- The map of the physical blocks of interest;
- List of crop codes used;
- List of crop classes to be followed (LCCF, i.e. very related groups of crops, which have similar aspect and phenological behaviour);
- A validation dataset, representative for the crop types / crop families' distribution, derived from very high resolution imagery or field visits.

Each area of interest is completely covered by the following Sentinel-2 granules (Fig. 4, Tables 1, 2, 3):

- Brăila county: 35TNL, 35TNK.
- Prut – Bârlad: 35TNL, 35TNM.
- Arad – Timiş: 34TDS, 34TES, 34TDR, 34TER.

Sentinel-2 data was downloaded from the online repository maintained by ESA (https://scihub.copernicus.eu/).

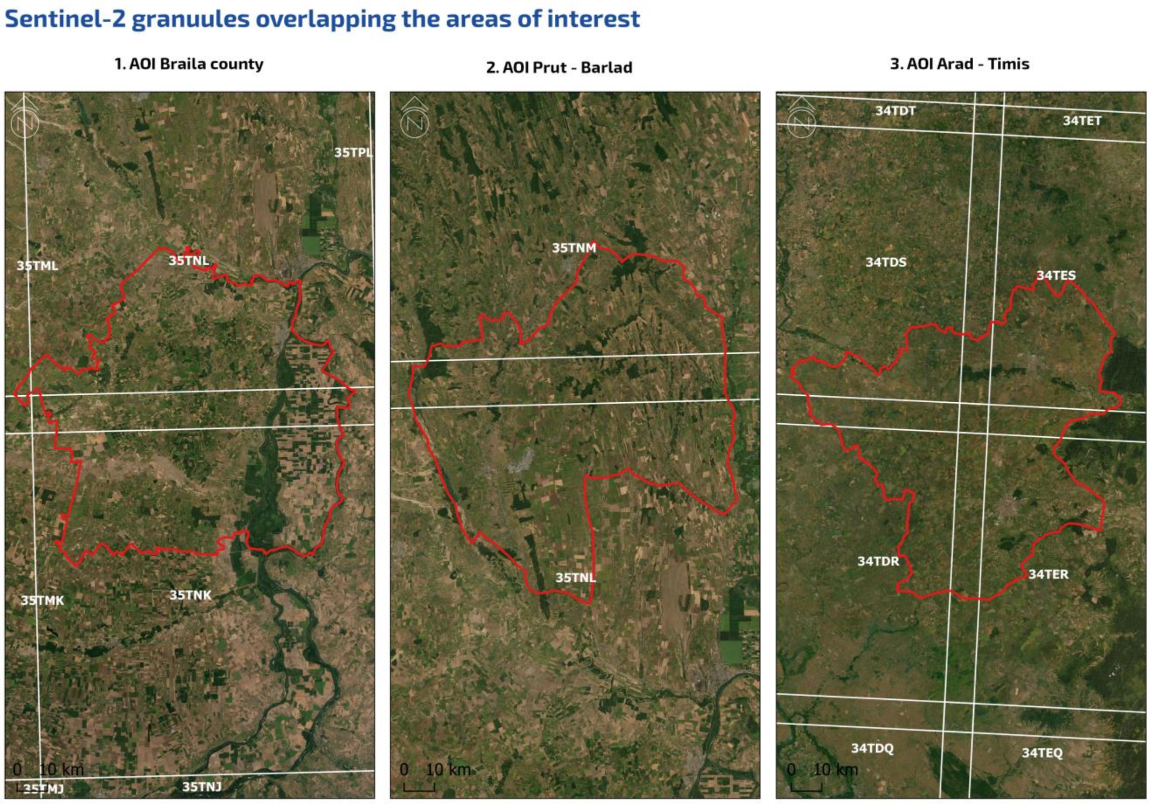


FIGURE 4: Sentinel-2 granules overlapping the area of interest

TABLE 1: Sentinel-2 granules - AOI 1 – Brăila county (T35TNL, T35TNK granules)

	T35TNL				T35TNK			
	No of scenes	Minimum cloud coverage (%)	Maximum cloud coverage (%)	Average cloud coverage (%)	No of scenes	Minimum cloud coverage (%)	Maximum cloud coverage (%)	Average cloud coverage (%)
III	12	0.00	99.65	45.62	12	0.00	99.90	48.72
IV	12	0.00	99.99	56.75	13	0.01	99.99	59.97
V	11	0.16	100.00	45.84	11	0.07	99.99	46.32
VI	12	0.00	73.00	20.01	13	0.00	70.90	23.63
VII	13	0.00	78.56	25.68	13	0.00	92.88	18.90
VIII	15	0.00	96.96	23.04	13	0.00	82.54	18.70
IX	10	0.00	99.42	43.88	10	0.00	99.61	43.73
	85	0.00	100.00	36.37	85	0.00	99.99	36.55

TABLE 2: Sentinel-2 granules - AOI 2 – Prut – Bârlad (T35TNL, T35TNM granules)

	T35TNL				T35TNM			
	No of scenes	Minimum cloud coverage (%)	Maximum cloud coverage (%)	Average cloud coverage (%)	No of scenes	Minimum cloud coverage (%)	Maximum cloud coverage (%)	Average cloud coverage (%)
III	12	0.00	99.65	45.62	13	0.00	99.73	48.31
IV	12	0.00	99.99	56.75	12	0.00	100.00	53.18
V	11	0.16	100.00	45.84	11	0.02	100.00	41.72

VI	12	0.00	73.00	20.01	12	0.00	65.16	13.50
VII	13	0.00	78.56	25.68	12	0.00	95.50	22.06
VIII	15	0.00	96.96	23.04	12	0.00	96.54	23.99
IX	10	0.00	99.42	43.88	10	0.01	93.39	38.19
	85	0.00	100.00	36.37	82	0.00	100.00	34.41

TABLE 3: Sentinel-2 granules - AOI 3 – Arad Timiş (T34TDS, T34TES, T34TDR, T34TER granules)

	T34TDS				T34TES			
	No of scenes	Minimum cloud coverage (%)	Maximum cloud coverage (%)	Average cloud coverage (%)	No of scenes	Minimum cloud coverage (%)	Maximum cloud coverage (%)	Average cloud coverage (%)
III	13	0.00	99.96	44.66	13	0.00	100.00	48.75
IV	11	0.01	98.52	43.08	11	0.03	93.47	44.18
V	12	14.87	99.99	73.17	12	30.82	99.99	76.79
VI	12	0.01	94.88	26.09	12	0.00	91.83	22.59
VII	13	0.00	99.33	32.81	13	0.00	99.17	30.59
VIII	12	0.00	66.85	17.10	12	0.00	95.49	21.67
IX	12	0.00	98.38	39.28	12	0.00	98.79	43.83
	85	0.00	99.99	39.40	85	0.00	100.00	41.13

	T34TDR				T34TER			
	No of scenes	Minimum cloud coverage (%)	Maximum cloud coverage (%)	Average cloud coverage (%)	No of scenes	Minimum cloud coverage (%)	Maximum cloud coverage (%)	Average cloud coverage (%)
III	12	0.00	100.00	54.67	16	0.00	100.00	54.13
IV	11	0.00	99.99	37.67	17	0.00	99.92	41.03
V	12	2.42	99.92	65.31	18	26.71	100.00	82.53
VI	12	0.00	99.99	24.81	18	0.00	99.99	32.59
VII	12	0.00	96.06	34.26	18	0.00	99.98	42.82
VIII	12	0.00	86.93	21.44	18	0.00	99.34	12.45
IX	12	0.17	99.05	30.41	19	0.00	99.98	30.64
	83	0.00	100.00	38.38	124	0.00	100.00	42.04

2.1.2 Methodology

The methodology consisted in two main steps, independent of each other:

- Crop type mapping;
- Mapping of irrigated areas.

Crop type mapping

Crop type mapping was performed based on an in-house developed fuzzy-based technique for crop detection and monitoring, based on combined free and open Sentinel-2 and Landsat-8 Earth Observation data image processing, data mining and machine learning algorithms, all integrated in a toolbox for crop identification and monitoring.

Starting from the 2018 agricultural season, TERRASIGNA has extended its CAP-related services and has monitored the declarations for the entire agricultural area of Romania, exceeding 9 million ha and corresponding to more than 6 million plots of various sizes and shapes. From our knowledge, the developed crop type maps represent the only product taking into account local/regional crop cultivation patterns and landscape particularities.

The crop monitoring technology developed by TERRASIGNA is able to recognize a large number of crops families, of the order of tens. For Romania, it addresses the first most cultivated 32 crop families (according to the information provided by the National Paying Agency), which together cover more than 97% of the agricultural land.

The processing chain involves a series of well-defined steps (Fig. 5):

- image pre-processing (numerical enhancements for Sentinel-2 and Landsat-8 scenes, ingestion of external data, clouds and shadows masking);
- individual scene classification;
- the use of unsupervised machine learning techniques in order to obtain the crop probability maps at scene level;
- time series analysis, making the system capable of recognizing several types of crops, of the order of several tens and allowing the generation of overall crop probability maps and derived products.

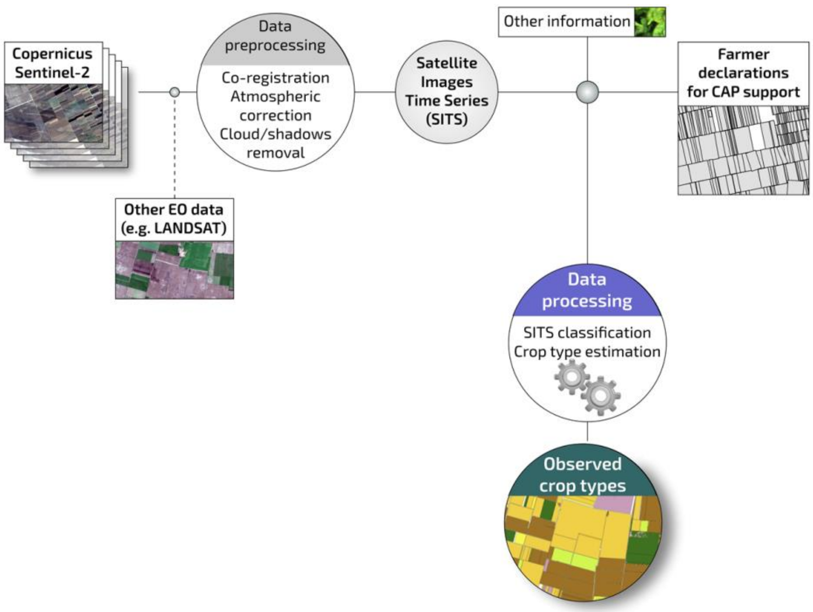


FIGURE 5: Crop type mapping methodology

The developed toolbox allows the automatic calculation of the maps with the main types of crops, for a completed annual agricultural cycle, delivered together with layers of additional information, showing the classification confidence index for the crop type maps computed (values closer to 1 show higher trust levels for the assessed parcels).

Mapping of irrigated areas

In order to be able to automatically determine the irrigated areas, some principles were used based on which several indexes (image descriptors) were built. The aforementioned principles are the following:

- The series of NDVI maps, calculated for the individual scenes during the interval March 1 - September 30, is sufficient to elucidate the phenomenon of irrigation;

- Irrigated surfaces are distinguished from others by higher NDVI intensity and dynamics;
- Controlling the phenomenon of contamination with clouds or shadows is essential to solve the problem (i.e. it is necessary to calculate and use cloud masks);
- It is necessary to analyze each area depending on the nature and phenology of the agricultural crop in play.

Thus, 4 descriptors were introduced:

- **Integral type descriptor**. Approximates the area of the subgraph given by the evolutionary curve of the NDVI, taking into account the contamination. It proved useful, the results obtained with the help of this index confirm the existing insights and information. However, it proves to be strongly correlated with the type of culture.
- **Average type descriptor 1**. Calculates the average of the NDVI values, only during the phenological manifestation of the plants, taking into account the contamination. It proved useful, the results obtained with the help of this index confirm the existing insights and information. It does not show a level of correlation as high with the type of culture as the other descriptors.
- **Average type descriptor 2**. Calculates the average of the NDVI values, during the phenological manifestation of the plants, without using cloud masks, but by the method of subintervals (for each subinterval of two months, the maximum NDVI is determined and only at the end an average is calculated of these values). It does not seem to lead to the desired resolution of the result.
- **Gradient type descriptor**. The sum of the gradient of the NDVI evolution curve (i.e. discrete derivative) is calculated, taking into account the contamination. The results are relatively good, but there is a lot of noise that is difficult to detect and it is extremely strongly correlated with the type of culture.

Finally, the results obtained with the **Integral** and **Average1** descriptors were included in the present report. For possible further developments, it is necessary to introduce filters that emancipate descriptors in relation to the type of culture, as well as calibrations that allow the use of all descriptors together, for a synthesis conclusion.

The developed method is pixel-based, which allows working without previous knowledge of the LPIS/plot plan and a maximum semantic resolution of the result (phenomena can be observed at the subplot scale).

Also, the index calculation algorithm did not integrate knowledge regarding the crop type, but only used simple techniques for automatically determining the phenological interval.

On the other hand, integrating information regarding the LPIS/plot plan and the crop type/crop class can open in the future the possibility of refining and correcting the results at a higher level of quality and precision.

2.2 Quantifying Irrigation Suitability. Multi-Criteria Assessment Analysis

The identification and mapping of potential irrigation sites, in order to enhance the capacity for resilience against drought events, was planned be performed through a Multi-criteria assessment (MCA), with the results allowing the creation of the suitability profiles of the three areas of interest for the implementation of irrigation projects.

Based on different datasets, both quantitative and qualitative, and previously established thresholds, the implementation team defined specific evaluation and decision markers that allowed the identification or proper areas for irrigated agriculture.

The MCA input included three main categories of factors/variables, related to water deficit, water supply potential and soil irrigation suitability, all computed based on different variables (Fig. 6, Table 4).

Finally, although it was initially planned to calculate a single Irrigation Suitability Index, following the internal analysis and discussions with stakeholders, it was decided that the study would be more valuable if the 3 components of the irrigation potential were presented separately, so that local patterns and specific situations could be easily identified and analysed.

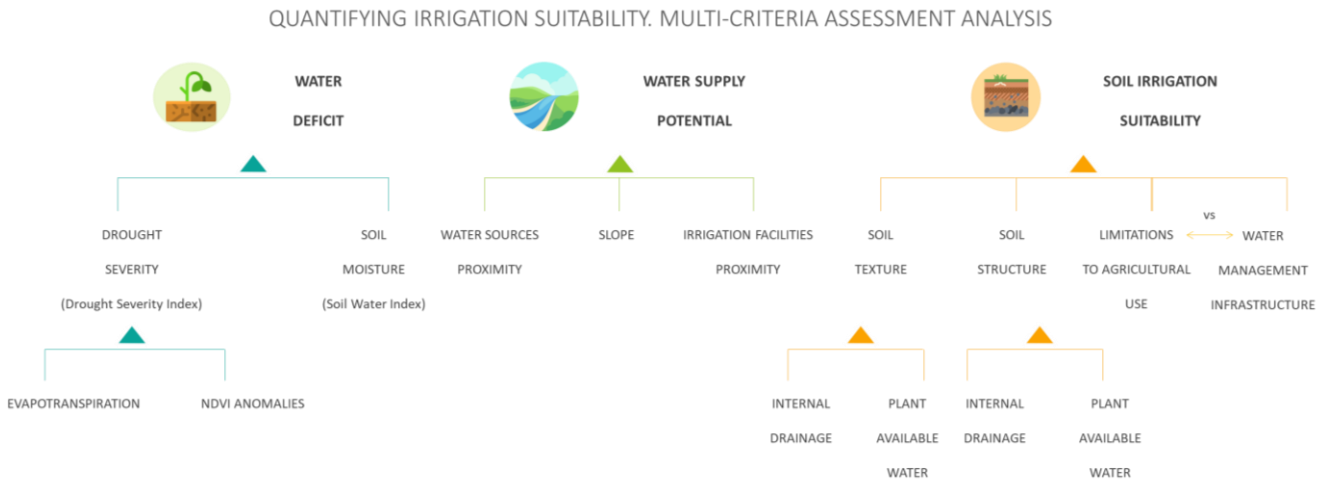


FIGURE 6: Quantifying irrigation suitability. Multi-criteria assessment variables

TABLE 4: Variables used for the quantification of irrigation suitability

	VARIABLE	SOURCE
WATER DEFICIT	Evapotranspiration	MODIS Evapotranspiration - Net Evapotranspiration 8-Day L4 Global 500m
	NDVI (NDVI Anomalies)	MODIS Vegetation Index Products (NDVI) - Vegetation Indices 16-Day L3 Global 250m
	Soil Water Index (SWI)	Copernicus Global Land Service. Bauer-Marschallinger et al., 2018.
WATER SUPPLY POTENTIAL	Freshwater resources	Romania's topographic reference plan, corresponding to the scale 1: 50000 (TopRo50). Data owner: ANCPI - National Agency for Cadaster and Land Registration

	Existing irrigation infrastructure	Romania's topographic reference plan, corresponding to the scale 1: 50000 (TopR050). Data owner: ANCPI - National Agency for Cadaster and Land Registration
	Slope	Derived from EU-DEM v 1.1. European Environment Agency (EEA) under the framework of the Copernicus programme - copernicus@eea.europa.eu
SOIL IRRIGATION SUITABILITY	Soil texture	European Soil Database v2.0 (vector and attribute data). Panagos Panos. The European soil database (2006) GEO: connexion, 5 (7), pp. 32-33. ESDB v2.0: The European Soil Database distribution version 2.0, European Commission and the European Soil Bureau Network, CD-ROM, EUR 19945 EN, 2004.
	Soil structure	
	Limitations to agricultural use	
	Water management infrastructure	

2.2.1 Water Deficit

Water Deficit Index is derived based on two distinct separate indices (Fig. 7): one that reflects mainly the lack of water at plant level (Drought Severity Index) and another focused on the availability of water resources in the soil (Soil Water Index).

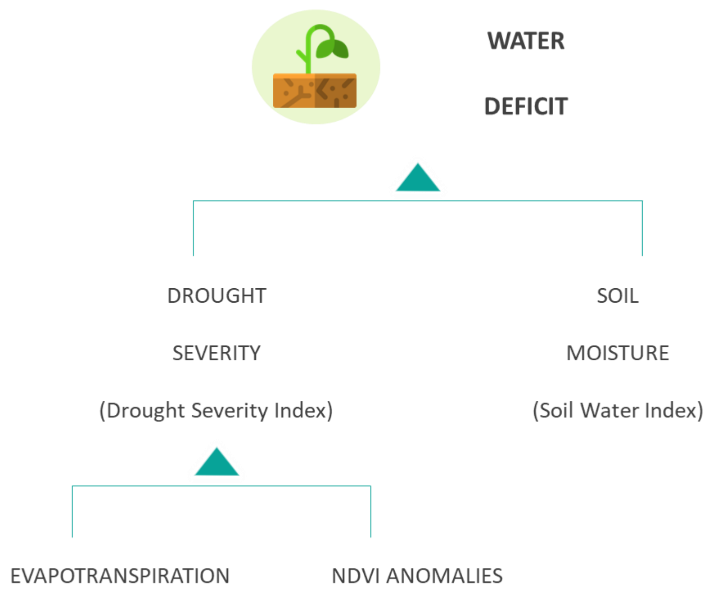


FIGURE 7: Water Deficit Index computation

Drought Severity Index (DSI) was first defined by Mu et al. (2013) as a response to incomplete existing drought indices, most of which were designed to detect hydrological and/or meteorological drought without taking into consideration the potential of remote sensing data to account for vegetation response.

In order to compute DSI, the ratio between ET (evapotranspiration) and PET (potential evapotranspiration) is first determined. The standardized ratio and standardized NDVI, at each grid cell, are then summed up in order to derive DSI.

$$z = \frac{ET / PET - \overline{ET / PET}}{\sigma_{ET / PET}} + \frac{NDVI - \overline{NDVI}}{\sigma_{NDVI}}$$

$$DSI = \frac{z - \overline{z}}{\sigma_z}$$

, where:

- ET = Evapotranspiration;
- PET = Potential Evapotranspiration;
- ET/PET = Ratio;
- $\overline{ET / PET}$ —Ratio average (2015–2019);
- $\sigma_{ET/PET}$ = Standard deviation of Ratio (2015–2019);
- NDVI = Normalized Difference Vegetation Index;
- $\overline{NDVI}$ = Average of the NDVI (2015–2019);
- σ_{NDVI} = Standard deviation of NDVI (2015–2019);
- σ_z = Standard deviation of z (2015–2019);
- $\overline{z}$ —Average of the z (2015–2019).

For DSI computation, the following MODIS composite products were used (covering only the vegetation season, between March and September, each year):

- MOD13Q1 - Vegetation Indices; composite products at 16 days, 250 m spatial resolution; version 006 (https://lpdaac.usgs.gov/products/mod13q1v006)
- MOD16A2 - Evapotranspiration/Latent Heat Flux product; composite products at 8 days, 500 m spatial resolution; version 006 (https://lpdaac.usgs.gov/products/mod16a2v006)

Both MODIS products were filtered according to the quality control flags distributed with the data itself. Only NDVI values above a threshold of 0.2 were used in the process, in order to account for bare soil or partially bare soil scenarios. The product ratio between ET and PET was aggregated to a 16 days interval in order to match the temporal resolution of the NDVI dataset. Finally, 5 years of data (2015-2019) was used (65 individual NDVI and 130 ET/PET products).

Since soil moisture information is not directly used when DSI is computed, the Soil Water Index (SWI) daily products from Copernicus Global Land Service were considered as well, in order to have a complex overview on the water deficit spatial distribution. Yearly and multi-annual averages of the SWI were computed.

Finally, the multi-annual DSI and the mean SWI were combined using the following approach: for both indicators, a classification was performed based on the statistical distribution of values for a given area of interest. Percentiles (20, 40, 60 and 80%) were used to divide the DSI and SWI values into categories which were further reclassified, meaning values from 1 to 5 were assigned. Finally, the two indices were combined by summing up the two products, thus obtaining a minimum possible value of 2 (most prone to being affected by water deficit) and a maximum one of 10 (least likely to be affected by water deficit). This final indicator gives a **relative** (not absolute) image inside a specific region.

2.2.2 Water Supply Potential

The second factor included in the analysis is represented by the Water Supply Potential Index, derived from the following input data sources:

- EUDEM at 25m spatial resolution reprojected to EPSG:31700;
- Existing irrigation infrastructure: Romania's topographic reference plan, corresponding to the scale 1: 50000 (TopRo50);
- Freshwater sources (lake and rivers): Romania's topographic reference plan, corresponding to the scale 1: 50000 (TopRo50).

The Water Supply Potential Index is computed based on 4 independent variables (Fig. 8), which have been reclassified based on their suitability for the implementation of irrigation solution:

- Slope;
- Vertical Distance;
- Proximity to Freshwater Sources;
- Proximity to Existing Irrigation Facilities.

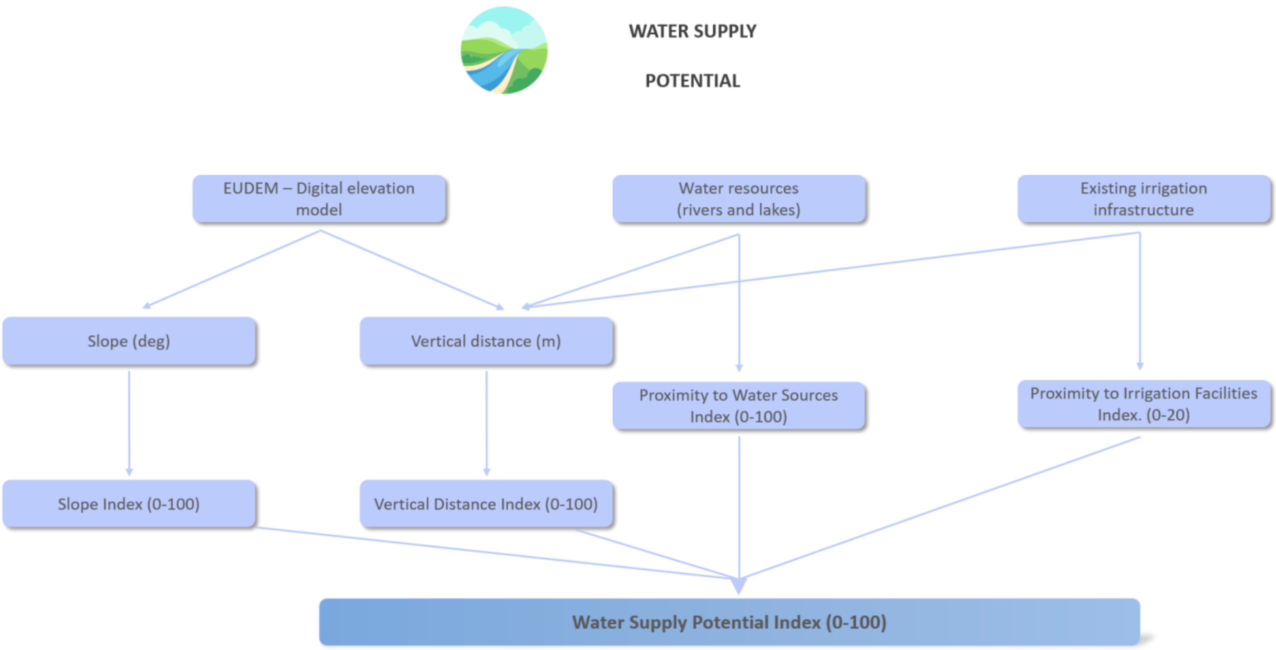


FIGURE 8: Water Supply Potential Index computation

The quantification of each variable is explained in the following tables.

Slope (degree) is derived from EUDEM. A reclassification was performed according to the following table, where 100 represent very favourable slope values, while 0 represent the least favourable slope values.

The output is represented by the Slope Index, with values ranging from 0 to 100.

TABLE 5: Slope reclassification rules

Minimum value (deg)	Maximum value (deg)	New (reclassified) value
0	1	100
1	3	90
3	5	80
5	7	70
7	10	60
10	15	40
15	20	20
20	90	0

Vertical distance (m) represents the altitude difference between a specific pixel and the closest water source or irrigation network. Vertical distance values were reclassified from 0 (unfavourable) to 100 (most favourable) according to Table 6.

The output is represented by the Vertical Distance Index, with values ranging from 0 to 100.

TABLE 6: Vertical distance reclassification rules

Minimum value (m)	Maximum value (m)	New (reclassified) value
0	2	100
2	4	80
4	6	60
6	10	40
10	15	20
15	20	10
25	30	5
30	1000	0

Proximity of water sources represents the distance (meters) from the closest water source for each pixel within a 5 kilometre buffer. Afterward, each pixel value was linearly scaled from 5000-0 to 0-100 interval (0 unfavourable, 100 favourable).

The output is represented by the Proximity to Water Sources Index, with values ranging from 0 to 100.

Proximity of irrigation facilities represents the distance (meters) from the irrigation facility for each pixel within a 1 kilometre buffer. Afterward, each pixel value was linearly scaled from 5000 - 0 to 0-100 interval (0 unfavourable, 100 favourable). The 5000-0 range was used, so that the proximity of an irrigation canal compared to a river or a lake has a smaller influence in the final index.

The output is represented by the Proximity to Irrigation Facilities Index, with values ranging from 0 to 20.

Finally, the Water Supply Potential Index can be calculated using the following formula:

Water Supply Potential Index = 0.4 (Max(Proximity to Water Sources Index, Proximity to Irrigation Facilities Index))+0.35* Vertical Distance Index+0.25* Slope Index

2.2.3 Soil Irrigation Suitability

A third category of factors included in the analysis is based on the spatial distribution of soil groups according to soil suitability for irrigation.

The main irrigation suitability factors considered (Fig. 9) were:

- Soil texture, including its effects on both soil properties relating to irrigation – internal drainage and plant available water;
- Soil structure, including its effects on both soil properties relating to irrigation – internal drainage and plant available water;
- Limitations to agricultural use;
- Existence of water management infrastructure used to remove the agricultural use limitations.

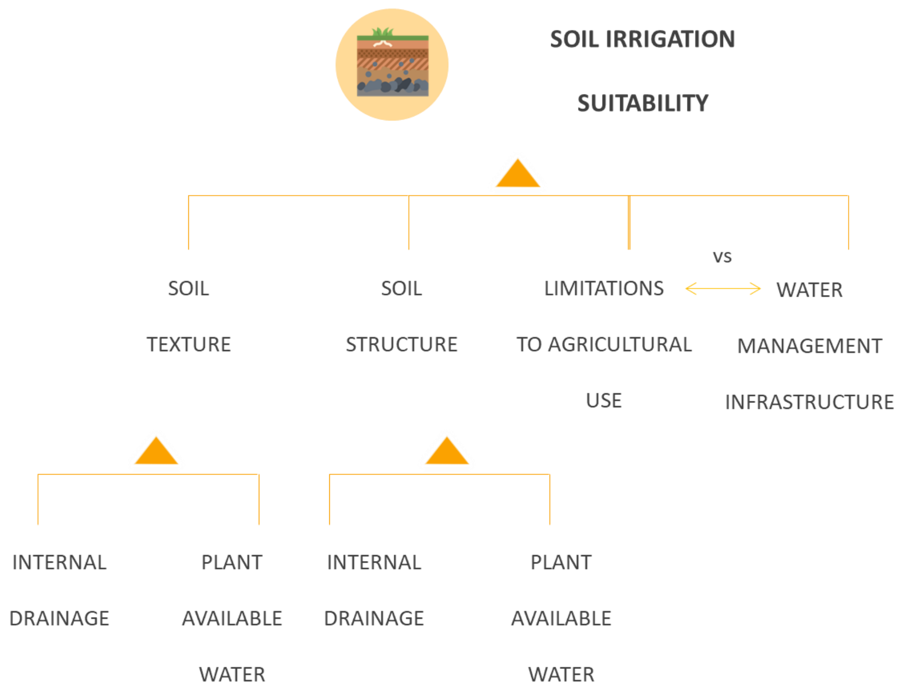


FIGURE 9: Variables used for Soil Irrigation Suitability assessment

The computation was based exclusively on the freely available ESDB v2.0: The European Soil Database distribution version 2.0. dataset provided by ESDAC (European Soil Data Centre), prepared for use by the Land Resource Management Unit (Institute for Environment & Sustainability) of the Joint Research Centre (JRC) of the European Commission.

The developed methodology was based on the FAO guideline for land evaluation, (1976, 1979, 1991 and 1999), as well as expert knowledge and research papers dedicated to best practices regarding soil suitability for irrigation (Schroeder et al., 2007; Brady and Weill, 2008; Hailu and Quraishi, 2017, Bezdan et al., 2019).

The following correspondence tables (Table 7, Table 8, Table 9, Table 10, Table 11, Table 12, Table 13) have been used in order to compute the Soil Irrigation Suitability Index.

TABLE 7: Correspondence of qualitative / quantitative scales used in calculating the Soil Irrigation Suitability Index

Property	Score
High	5
Medium-High	4
Medium	3
Medium-Low	2
Low	1

TABLE 8: Texture effects on soil properties relating to irrigation (*Schroeder et al., 2007*)

Soil property		**Soil texture**				
		Sand	**Loam**	**Silty loam**	**Sandy clay loam**	**Clay**
ESDAC ESDB correspondence		1 – ESDAC	2 – ESDAC	3 – ESDAC	4 – ESDAC	5 – ESDAC
		Coarse (18% < clay and > 65% sand)	*Medium (18% < clay < 35% and >= 15% sand, or 18% <clay and 15% < sand < 65%)*	*Medium fine (< 35% clay and < 15% sand)*	*Fine (35% < clay < 60%)*	*Very fine (clay > 60 %)*
Internal drainage	*Property*	High	Moderate	Moderate-low	Moderate-low	Moderate-low
	Score	5	3	2	2	2
Plant available water	*Property*	Low	Moderate	High	Moderate	Moderate-high
	Score	1	3	5	3	4

It can be observed that a medium texture is considered the most favourable in terms of irrigation suitability, as it imprints favourable properties on the soil regarding water content, air content, permeability, nutrient content and, in general, humus content.

Regarding the types of irrigation systems used depending on the texture of the soil, the following aspects should be taken into account:

- Clay retains and stores more water (double amount) than sandy or coarse-textured porous soils, especially in the plant root area. On the other hand, clay absorbs and releases water very slowly. In the presence of clay it is easier for water to flow instead of going deep. For clay soils, the most suitable solutions involve a system of irrigation with low flow and irrigation in mini-cycles of several tens of minutes, in order to avoid water waste.
- On the contrary, sandy soils can be irrigated with systems that distribute water at high flows. Water enters them easily, but it comes out just as easily. To maintain the moisture of this type of soil, they should be watered in shorter, but more frequent cycles.

TABLE 9: Structure effects on soil properties relating to irrigation (*Schroeder et al., 2007*)

Soil property		**Level of soil structure**				
		Structureless	**Weak**	**Moderate**	**Strong blocky**	**Strong prismatic**
ESDAC ESDB correspondence		Humic or Peaty soil	Poor	Normal	Good	
Internal drainage	*Property*	Moderate-high	Low-Moderate	Moderate	Moderate	Low (within) Moderate-high (between)
	Score	4	2	3	3	2
Plant available water	*Property*	Low	Moderate-high	Moderate	Moderate-high	Low
	Score	1	4	3	4	1

It can be observed that a good structure (strong blocky) is considered the most suitable for irrigation purpose, allowing for improved infiltration and drainage. It also enhances root growth and provides the plant with the ability to access a greater amount of water and nutrients. On the other side, poor structure reduces infiltration and water holding ability and will make irrigation more difficult to manage.

Though soil texture remains constant, destructive tillage practices and compaction can destroy soil structure. Therefore, studies on soil structure and its suitability for irrigation should be updated periodically.

A set of complementary factors was also introduced in the analysis: Limitations to agricultural use (Table 10) versus Existence of water management infrastructure (Table 12, Table 13) used to remove the agricultural use limitations.

The agricultural use limitations included in the table below have been analysed, quantified according to their impact (including cumulated impact) and grouped into irrigation suitability classes (Table 11).

TABLE 10: Agricultural use limitations included as ESDAC ESDB attributes (*Panos, 2006, ESDB v2.0*)

ESDAC ESDB Code	**Agricultural use limitation**
0	No information
1	No limitation to agricultural use
2	Gravelly (over 35% gravel diameter < 7.5 cm)
3	Stony (presence of stones diameter > 7.5 cm, impracticable mechanisation)
4	Lithic (coherent and hard rock within 50 cm)
5	Concretionary (over 35% concretions diameter < 7.5 cm near the surface)
6	Petrocalcic (cemented or indurated calcic horizon within 100 cm)
7	Saline (electric conductivity > 4 mS.cm-1 within 100 cm)
8	Sodic (Na/T > 6% within 100 cm)
9	Glaciers and snow-caps
10	Soils disturbed by man (i.e. landfills, paved surfaces, mine spoils)
11	Fragipans
12	Excessively drained
13	Almost always flooded
14	Eroded phase, erosion

ESDAC ESDB Code	Agricultural use limitation
15	Phreatic phase (shallow water table)
16	Duripan (silica and iron cemented subsoil horizon)
17	Petroferric horizon
18	Permafrost

TABLE 11: Irrigability classes and scores according to agricultural use limitations (after *Bezdan et al., 2019*)

Irrigability Class	Description	Score
I	No limitation for sustained use under irrigation	1
II	Slight soil limitation for sustained use under irrigation	2
IIIa	Moderate soil limitation for sustained use under irrigation	3
IIIb	Severe soil limitation for sustained use under irrigation	4
IIIc	Very severe soil limitation for sustained use under irrigation	5

The information regarding the water management infrastructure used to overcome the agricultural limitations is given in the tables below.

In computing soil suitability for irrigation, if a limitation finds its counterpart in a water management infrastructure category, the dedicated score is cancelled / removed from the equation.

TABLE 12: Water management systems included as ESDAC ESDB attributes (*Panos, 2006, ESDB v2.0*)

ESDAC ESDB Code	Water Management 1
0	No information
1	Not applicable (no agriculture)
2	No water management system
3	A water management system exists to alleviate waterlogging (drainage)
4	A water management system exists to alleviate drought stress (irrigation)
5	A water management system exists to alleviate salinity (drainage)
6	A water management system exists to alleviate both waterlogging and drought stress
7	A water management system exists to alleviate both waterlogging and salinity

TABLE 13: Water management infrastructure elements included as ESDAC ESDB attributes (*Panos, 2006, ESDB v2.0*)

ESDAC ESDB Code	Water Management 2
0	No information
1	Not applicable (no agriculture)
2	No water management system
3	Pumping
4	Ditches

ESDAC ESDB Code	Water Management 2
5	Pipe under drainage (network of drain pipes)
6	Mole drainage
7	Deep loosening (subsoiling)
8	Bed system (ridge-funow or steching)
9	Flood irrigation (system of irrigation by controlled flooding as for rice)
10	Overhead sprinkler (system of irrigation by sprinkling)
11	Trickle irrigation

The final Soil Irrigation Suitability Index is computed using the following formula:

Soil Irrigation Suitability Index = (ST_D * ST_W) + (SS_D * SS_W) – AGLIM + WM

, where:

- **ST_D** = Soil texture effect on internal drainage (scores between 1 - 5);
- **ST_W** = Soil texture effect on plant available water (scores between 1 - 5);
- **SS_D** = Soil structure effect on internal drainage (scores between 1 - 5);
- **SS_W** = Soil structure effect on plant available water (scores between 1 - 5);
- **AGLIM** = Agricultural use limitations imposed by soil properties (scores between 1 - 5);
- **WM** = Existence of water management infrastructure used to remove the agricultural use limitations (scores between 1 - 5).

The final values are reclassified as follows:

TABLE 14: Soil Irrigation Suitability Index – Reclassified values

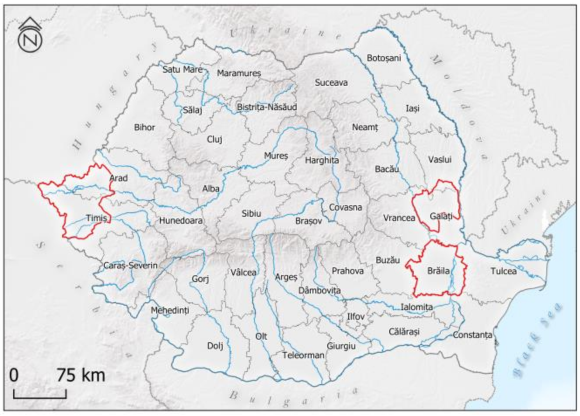
Score	Reclassified Value	Description
>20	1	Most suitable for the use of irrigation systems
15 – 20	0.8	Medium high suitabiliy for the use of irrigation systems
10 – 15	0.6	Medium suitability for the use of irrigation systems
5 – 10	0.4	Medium low suitability for the use of irrigation systems
< 5	0.2	Least suitable for the use of irrigation systems
0	0	No data

3 DELIVERED EO-BASED PRODUCTS AND SERVICES

Based on the methodologies explained in the previous chapter, EO-based products have been computed for three pilot sites.

The chosen areas of interest cover more than 14k sqkm and are localized in 3 different parts of the country. They are characterized by geographical diversity (relief, climate, soils), diversity of crop types, as well as varied socio-economic conditions. Moreover, although in all 3 areas there have been irrigation systems for decades, now they are underused (Fig. 10), thus contributing to economically unviable agricultural management.

Proposed areas on interest



Area of interest (AOI)	Area (sqkm)	Major relief units
1.Brăila county	4766	Romanian Plain
2. Prut - Bârlad	3031	Romanian Plain / Bârlad Plateau
3. Arad - Timiș	6498	Western Plain

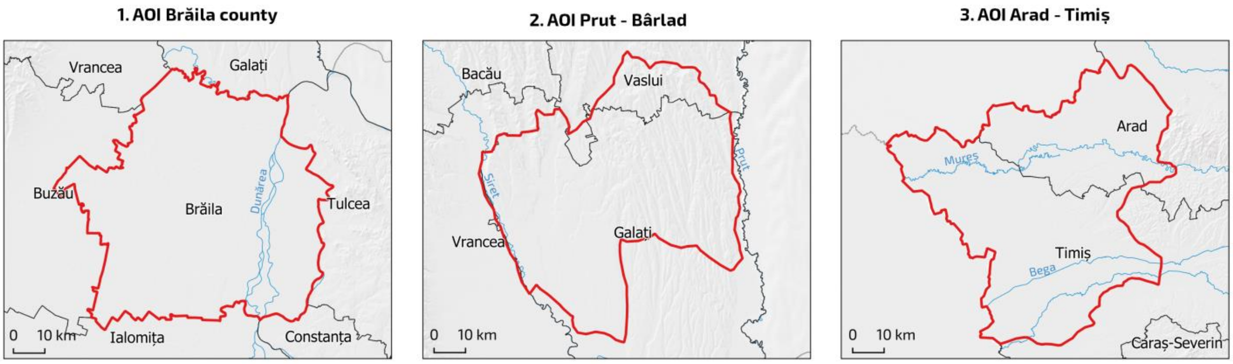


FIGURE 10: Selected areas of interest (AOIs)

3.1 Mapping of Irrigated Areas, 2019

A first category of products is represented by the mapping of irrigated areas and corresponding crop types.

The mapping and spatial analysis of current irrigation areas over the selected AOIs was conducted based on high-resolution data (Sentinel, Landsat) for an agricultural cycle completed (2019).

3.1.1 Specifications

The products delivered within the Irrigated Areas Mapping task and their specifications are listed in Table 15.

All the geospatial products are delivered in the Romanian national projection (Stereo 70 – EPSG31700), according to the needs of the beneficiary. Each dataset is accompanied by an ISO standard compliant metadata file (xml format) with all relevant product details.

All the maps and charts are also delivered separately, as .png files.

All products are delivered through the client preferred channel and will remain available for download for at least 12 months following initial delivery.

TABLE 15: Products delivered within the Irrigated Areas Mapping task

Product	Count	Resolution	Format	Accuracy
MAPPING OF IRRIGATED AREAS				
Irrigated areas classification (2019)	1	10 m	GeoTIFF / SHP	NA
Crop Type Map (2019)	1	10 m	GeoTIFF / SHP	>90%
Confidence Index – Crop Type Map	1	10 m	GeoTIFF	-
Relevant Statistics	1	-	Table (XLS / CSV)	-
Metadata file	1	-	XML	-

3.1.2 Outputs

3.1.2.1 AOI1 – Brăila County. Mapping of irrigated areas, 2019

The first AOI, Brăila County (Fig. 11), is located in the eastern part of the country, in the Romanian Plain.

Suitable geographical positioning, relief, climate and fertile soils favour the practice of intensive agriculture. The agricultural area of the county occupies over 80% of the territory, with a clear dominance of arable land (approximately 74% of AOI).

The crop type map produced by TERRASIGNA (Fig. 12, Fig. 13, Table 16) indicates that 3 crop classes cover together approximately 75% of the total surface of the AOI. Dominant crop classes are: maize (over 135 000 ha, summing more than 35% of the surface of the AOI), autumn wheat (more than 80 000 ha, summing more than 21% of the surface of the AOI), sunflower (more than 67 000 ha, summing more than 17% of the total area of the AOI). Other important crop classes are pasture / grassland (distributed especially along the main rivers within the AOI), autumn barley, soybean or lucerne / alfalfa.

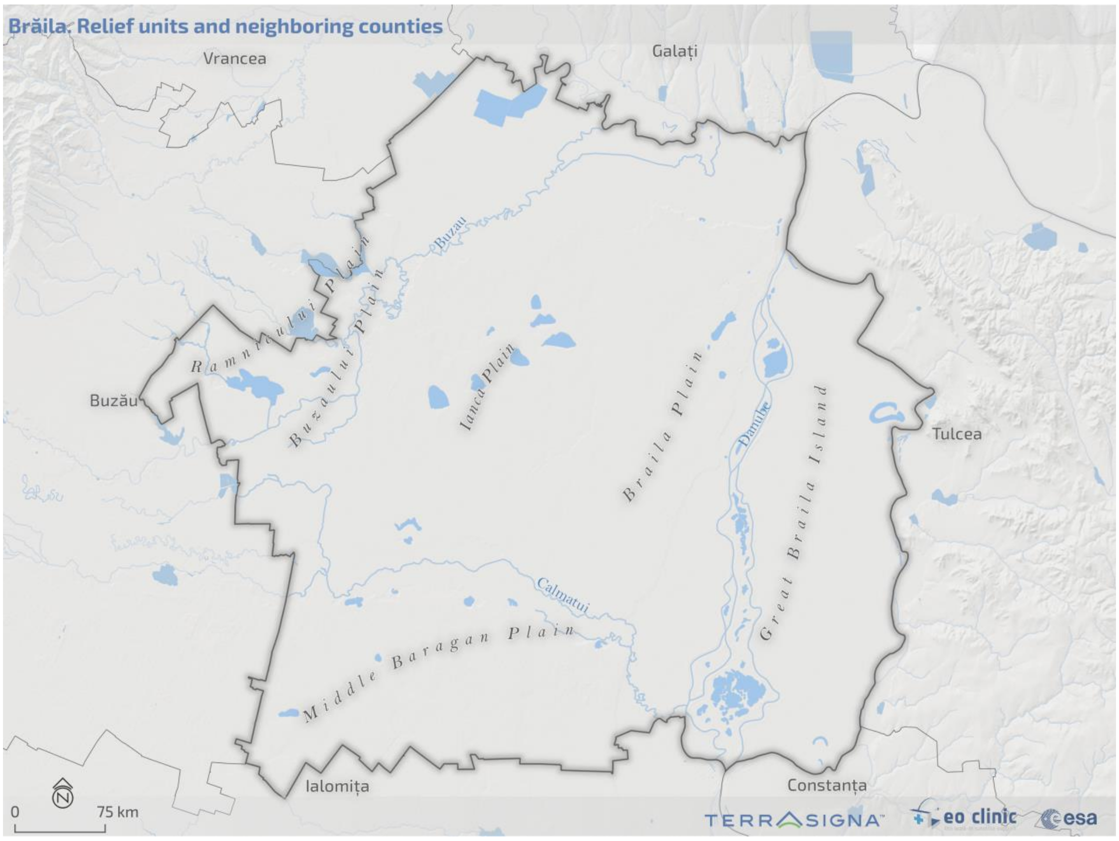


FIGURE 11: Brăila County. Relief units and neighbouring counties

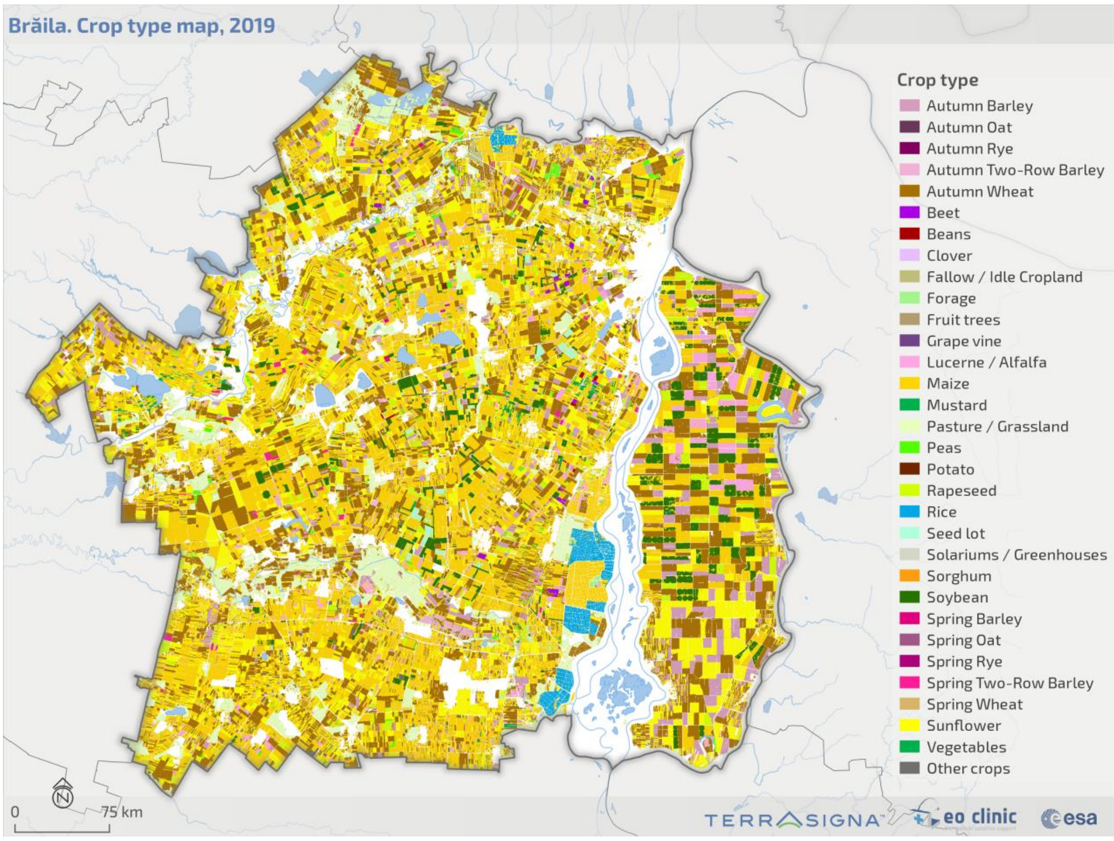


FIGURE 12: Brăila County. Crop type map, 2019

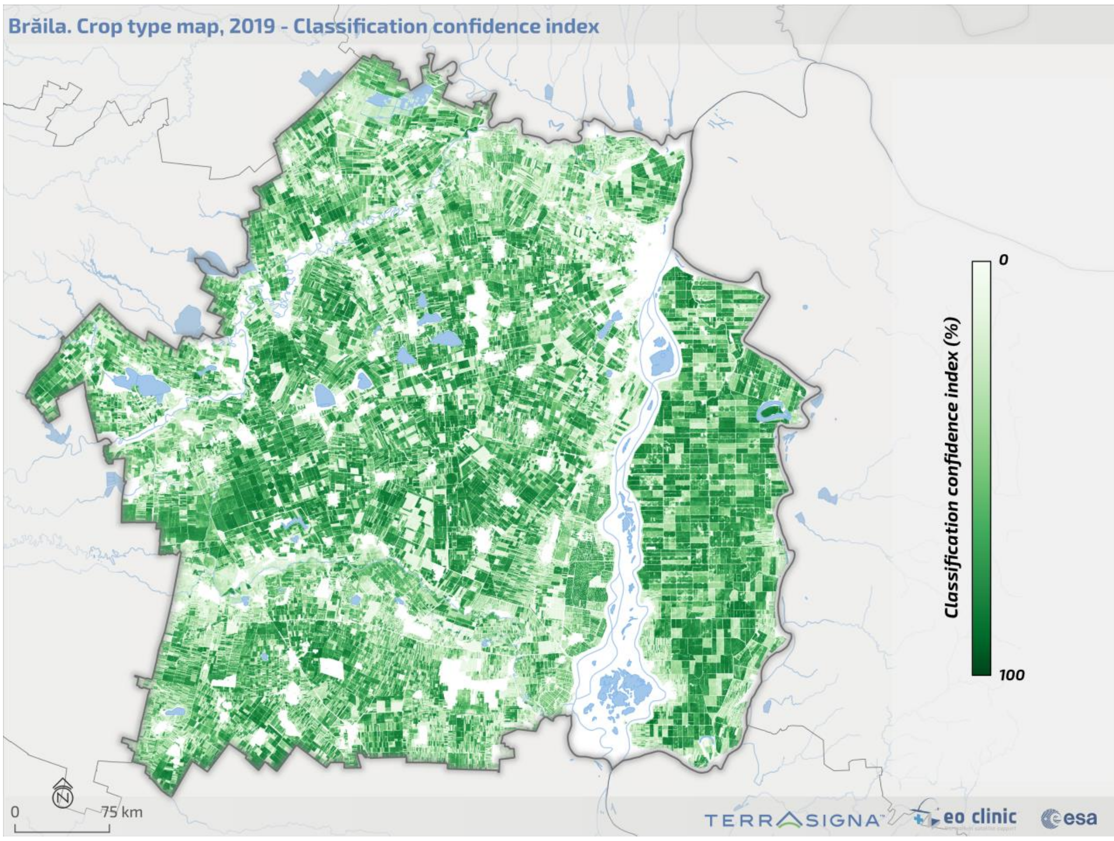


FIGURE 13: Brăila County. Classification confidence index corresponding to the crop type map, 2019

TABLE 16: Brăila County. Crop classes (2019) and areas covered

Crop Class	*Area (ha)*	*Percentage (%)*
Autumn Barley	18129.09	4.79
Autumn Oat	75.3	0.02
Autumn Rye	3.88	0.00
Autumn Two-Row Barley	1622.34	0.43
Autumn Wheat	81928.53	21.65
Beans	233.24	0.06
Beet	556.5	0.15
Clover	2.47	0.00
Fallow / Idle Cropland	412.62	0.11
Forage	641.14	0.17
Fruit trees	129.49	0.03
Grape vine	53.99	0.01
Lucerne/Alfalfa	11569.97	3.06
Maize	135066.78	35.69
Mustard	54.09	0.01
Pasture/Grassland	27908.91	7.37
Peas	2782.03	0.74
Potato	69.44	0.02
Rapeseed	5619.17	1.48
Rice	3586.72	0.95
Seed lot	1758.88	0.46
Solariums / Greenhouses	8.02	0.00
Sorghum	2.45	0.00
Soybean	14568.1	3.85
Spring Barley	171.66	0.05
Spring Oat	203.69	0.05
Spring Rye	0.36	0.00
Spring Two-Row Barley	1184.23	0.31
Spring Wheat	90.82	0.02
Sunflower	67608.37	17.86
Vegetables	1211.34	0.32
Other crops	1195.77	0.32
Total	*378449.39 ha*	

In terms of irrigated areas classification (Fig. 14), Brăila county presents one of the largest irrigated areas among the counties located in the south-eastern part of the country. The determined irrigated areas cover 134 631 hectares, corresponding to 28% of the AOI and 35.5% of the agricultural area of the AOI. Compact irrigated areas can be observed in the centre of the county, as well as along the Danube river: in the western part of the river there are rice fields cultivated in flooded regime, while in the eastern part there are irrigated fields belonging to the Great Brăila Island, which turned to agricultural land after drainage. The area is also characterized by a vast network of dams and irrigation canals, thus becoming one of the most productive agricultural areas in the country, but characterized by a deeply artificialized landscape.

Also, different patterns were noticed in the analysis: the compact irrigated areas often correspond to the irrigations carried out with the help of dedicated channels and specific sprinklers, while for the areas where a dispersion tendency is noticed, it can be assumed that they represent fields irrigated by more modern systems, such as drip irrigation.

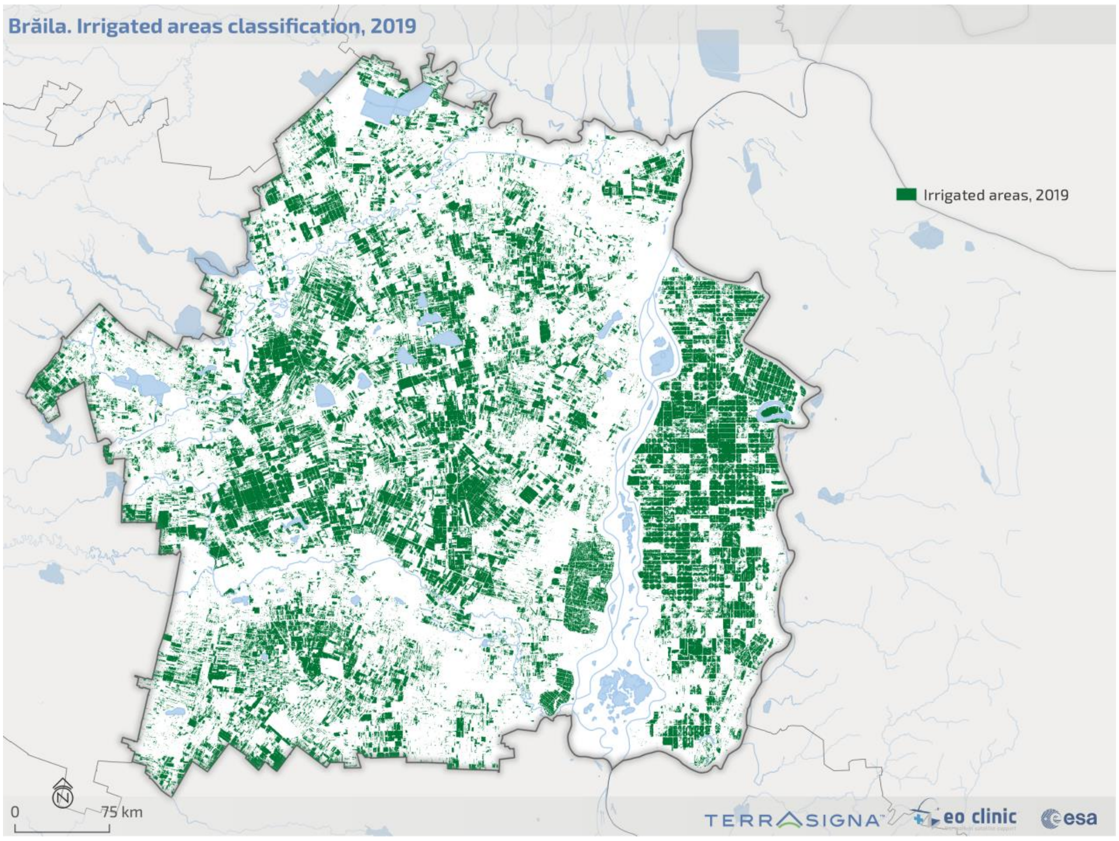


FIGURE 14: Brăila County. Irrigated areas classification, 2019

Regarding irrigated crops (Fig. 15, Fig. 16, Table 17), there is a dominance of spring crops, such as corn or sunflower, which together cover over 65% of irrigated crops in the area of interest. Important percentages of irrigated areas are also noted within crop classes (e.g. sunflower - more than 50% irrigated surface).

Also, there can be noticed the presence of crops whose phenological cycle depends on irrigation in these climatic conditions, such as soybean (93.60% irrigated surface within the crop class) or rice, cultivated in flood regime.

Autumn crops are usually harvested early in this AOI, so the percentage occupied by irrigated areas is lower than expected in classes such as autumn wheat or autumn barley.

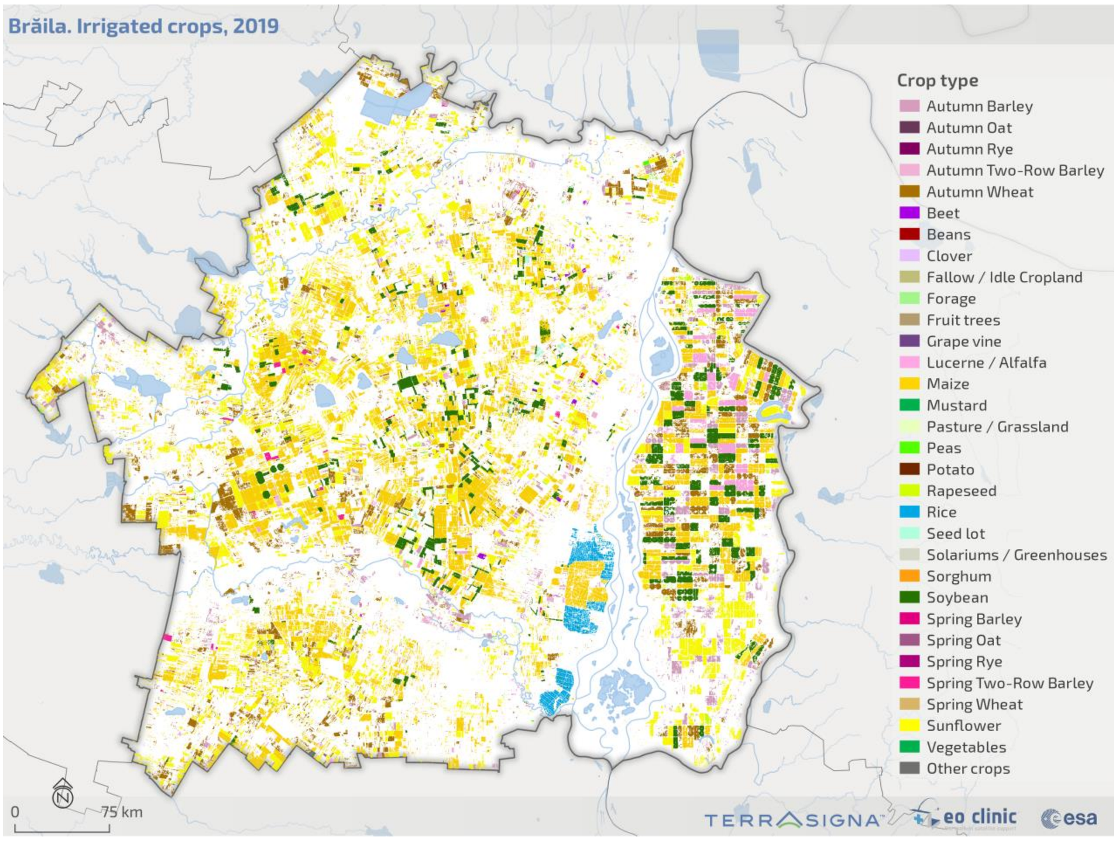


FIGURE 15: Brăila County. Irrigated crops, 2019

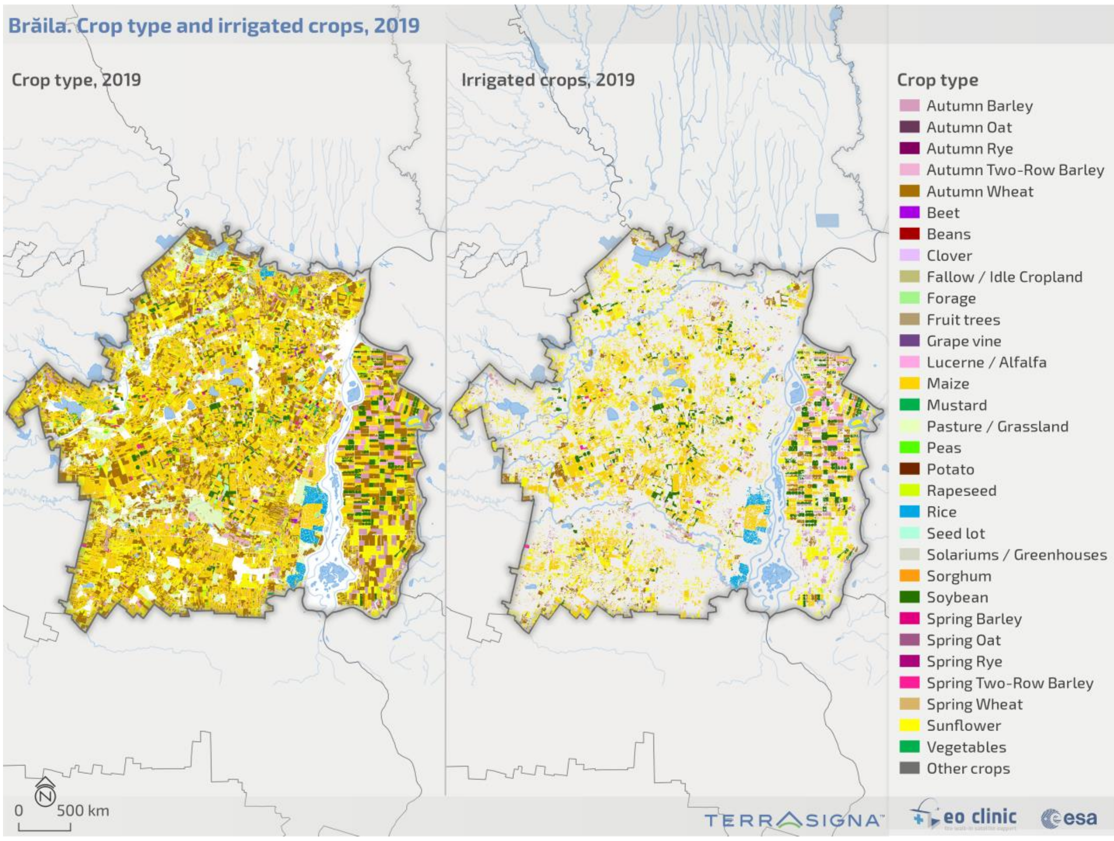


FIGURE 16: Brăila County. Crop type map versus irrigated crop type map, 2019

TABLE 17: Brăila County. Crop classes (2019) and irrigated areas

Crop Class	*Total surface covered (ha)*	*Percentage of AOI's agricultural land (%)*	*Irrigated surface (ha)*	*Percentage of irrigated surface within the crop class (%)*	*Percentage of total irrigated crops (%)*
Autumn Barley	18129.09	4.79	6808.06	37.55	5.06
Autumn Oat	75.3	0.02	7.5	9.96	0.01
Autumn Rye	3.88	0.00	0.44	11.34	0.00
Autumn Two-Row Barley	1622.34	0.43	616.14	37.98	0.46
Autumn Wheat	81928.53	21.65	15344.67	18.73	11.40
Beans	233.24	0.06	56.31	24.14	0.04
Beet	556.5	0.15	231.39	41.58	0.17
Clover	2.47	0.00	0.1	4.05	0.00
Fallow / Idle Cropland	412.62	0.11	10.16	2.46	0.01
Forage	641.14	0.17	16.18	2.52	0.01
Fruit trees	129.49	0.03	0.09	0.07	0.00
Grape vine	53.99	0.01	0.16	0.30	0.00
Lucerne/Alfalfa	11569.97	3.06	3863.63	33.39	2.87
Maize	135066.78	35.69	53926.05	39.93	40.05
Mustard	54.09	0.01	0.27	0.50	0.00
Pasture/Grassland	27908.91	7.37	135.35	0.48	0.10
Peas	2782.03	0.74	296.79	10.67	0.22
Potato	69.44	0.02	38.06	54.81	0.03
Rapeseed	5619.17	1.48	775.3	13.80	0.58
Rice	3586.72	0.95	2420.24	67.48	1.80
Seed lot	1758.88	0.46	219.3	12.47	0.16
Solariums / Greenhouses	8.02	0.00	-	-	-
Sorghum	2.45	0.00	0.02	0.82	0.00
Soybean	14568.1	3.85	13636.39	93.60	10.13
Spring Barley	171.66	0.05	9.22	5.37	0.01
Spring Oat	203.69	0.05	25.38	12.46	0.02
Spring Rye	0.36	0.00	0.1	27.78	0.00
Spring Two-Row Barley	1184.23	0.31	527.29	44.53	0.39
Spring Wheat	90.82	0.02	41.02	45.17	0.03
Sunflower	67608.37	17.86	35519.56	52.54	26.38
Vegetables	1211.34	0.32	58.81	4.85	0.04
Other crops	1195.77	0.32	47.82	4.00	0.04

3.1.2.2 AOI2 – Prut-Bârlad. Mapping of irrigated areas, 2019

The second AOI, Prut-Bârlad (Fig. 17), is an area often affected by drought, especially in the southern, lower areas.

The crop type map produced by TERRASIGNA (Fig. 18, Fig. 19, Table 18) indicates that the same 3 crop classes cover together approximately 75% of the total surface of the AOI. Dominant crop classes are: maize (over 87 000 ha, summing more than 38% of the surface of the AOI), sunflower (almost 45 000 ha, summing more than 19% of the total area of the AOI) and autumn wheat (more than 39 000 ha, summing more than 17% of the surface of the AOI). Pasture / grassland also cover important areas, accounting for almost 15% of the total agricultural area of the analysed AOI.

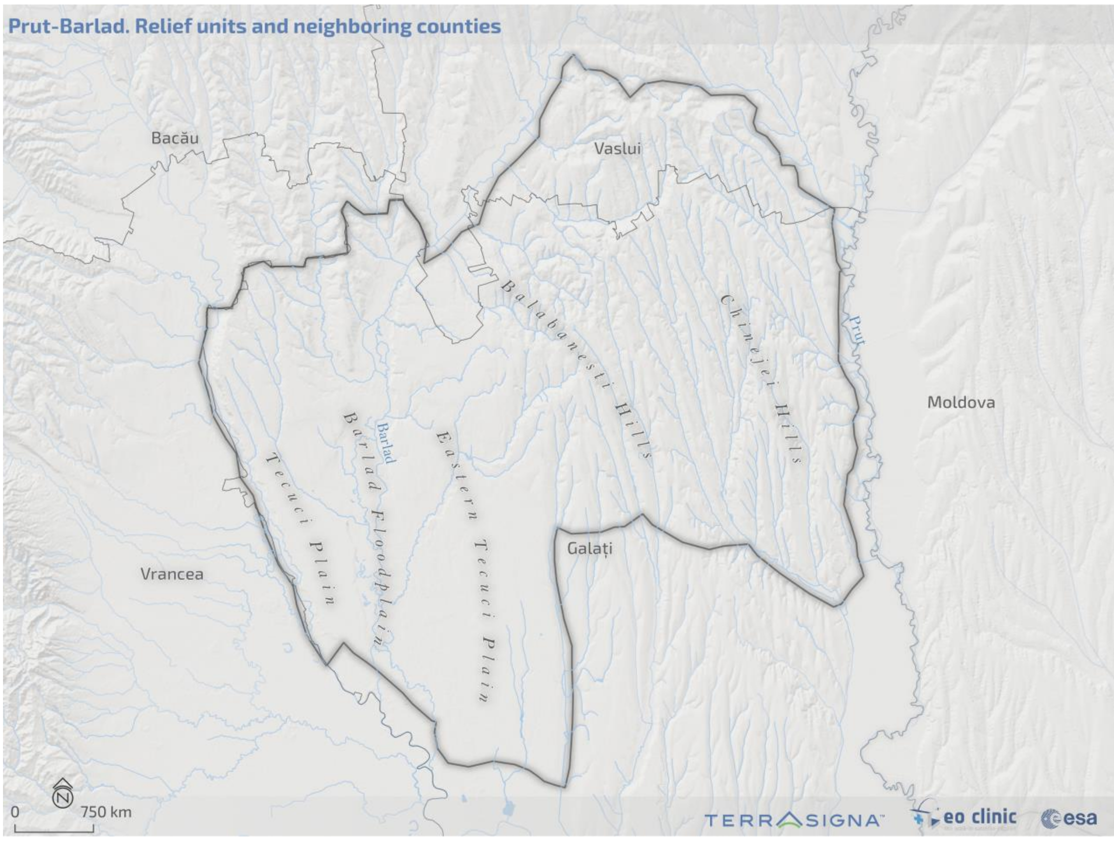


FIGURE 17: Prut-Bârlad. Relief units and neighbouring counties

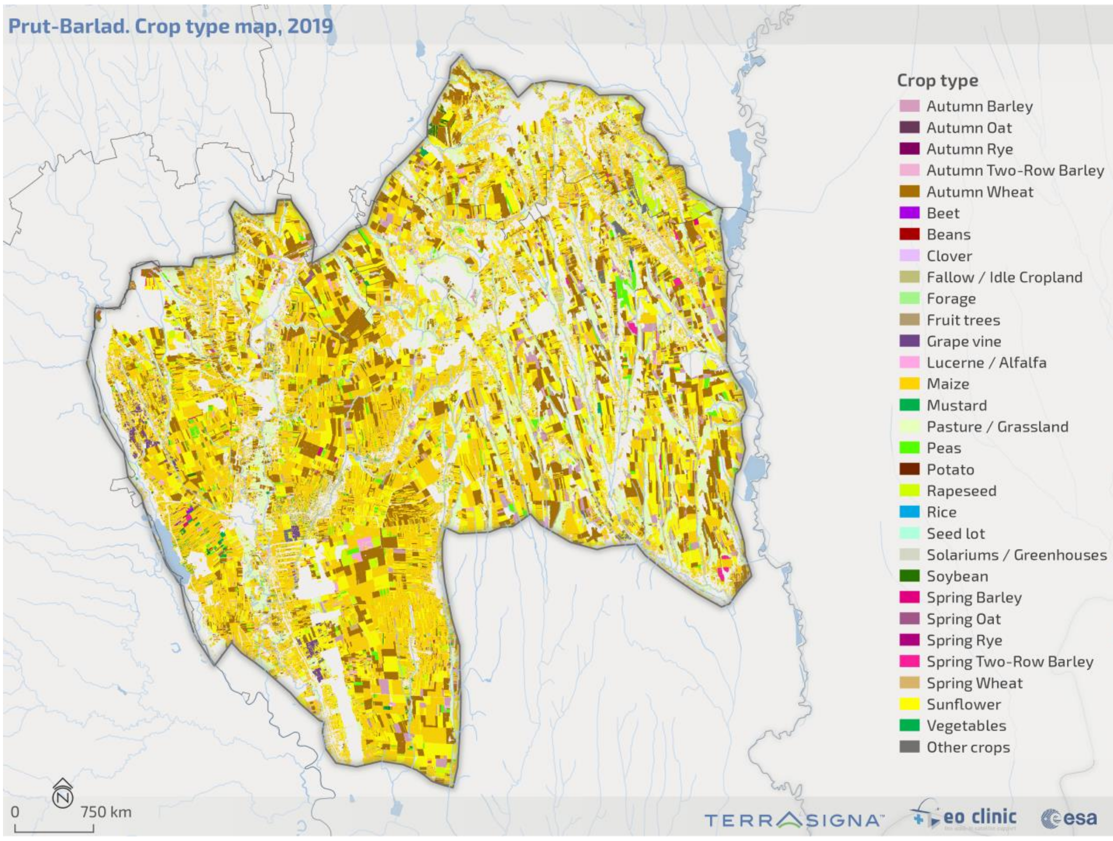


FIGURE 18: Prut-Bârlad. Crop type map, 2019

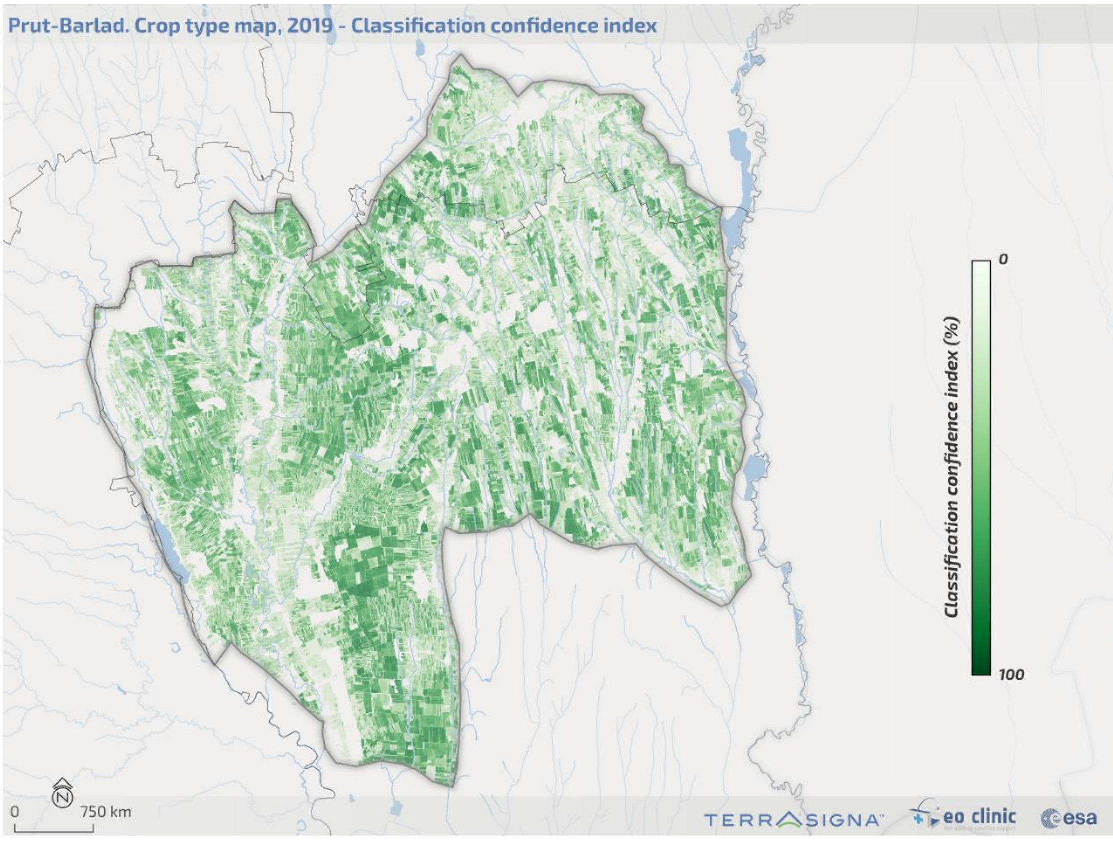


FIGURE 19: Prut-Bârlad. Classification confidence index corresponding to the crop type map, 2019

TABLE 18: Prut-Bârlad. Crop classes (2019) and areas covered

Crop Class	Area (ha)	Percentage (%)
Autumn Barley	4988.72	2.17
Autumn Oat	62.33	0.03
Autumn Rye	13.64	0.01
Autumn Two-Row Barley	72.98	0.03
Autumn Wheat	39502.06	17.16
Beans	147.31	0.06
Beet	45.18	0.02
Clover	2.02	0.00
Fallow / Idle Cropland	205.13	0.09
Forage	1143.57	0.50
Fruit trees	208	0.09
Grape vine	1264.61	0.55
Lucerne/Alfalfa	4934.84	2.14
Maize	87780.05	38.12
Mustard	157.43	0.07
Pasture/Grassland	33952.64	14.75
Peas	2860.04	1.24
Potato	9.88	0.00
Rapeseed	3749.31	1.63
Rice	0.71	0.00
Seed lot	39.13	0.02
Solariums / Greenhouses	439.17	0.19
Soybean	377.57	0.16
Spring Barley	167.65	0.07
Spring Oat	270.1	0.12
Spring Rye	2.03	0.00
Spring Two-Row Barley	1018.47	0.44
Spring Wheat	65.78	0.03
Sunflower	44498.42	19.33
Vegetables	807.19	0.35
Other crops	1464.78	0.64
Total	230250.74 ha	

In terms of irrigated areas classification (Fig. 20), the determined irrigated fields total 27 102 hectares, corresponding to almost 9% of the AOI and 11.8% of the agricultural area of the AOI, which is rather marked by dispersed irrigated zones. The most compact irrigated crop areas are located in the eastern part of Bârlad Floodplain, in the Eastern Tecuci Plain. Tendencies of concentration of irrigated plots are also noticeable in the Bălăbănești Hills and the Chinejei Hills. At the opposite pole, the Western Tecuci Plain, located west of Bârlad Valley, more fragmented in terms of relief, is distinguished by accentuated tendencies of dispersion of irrigated areas.

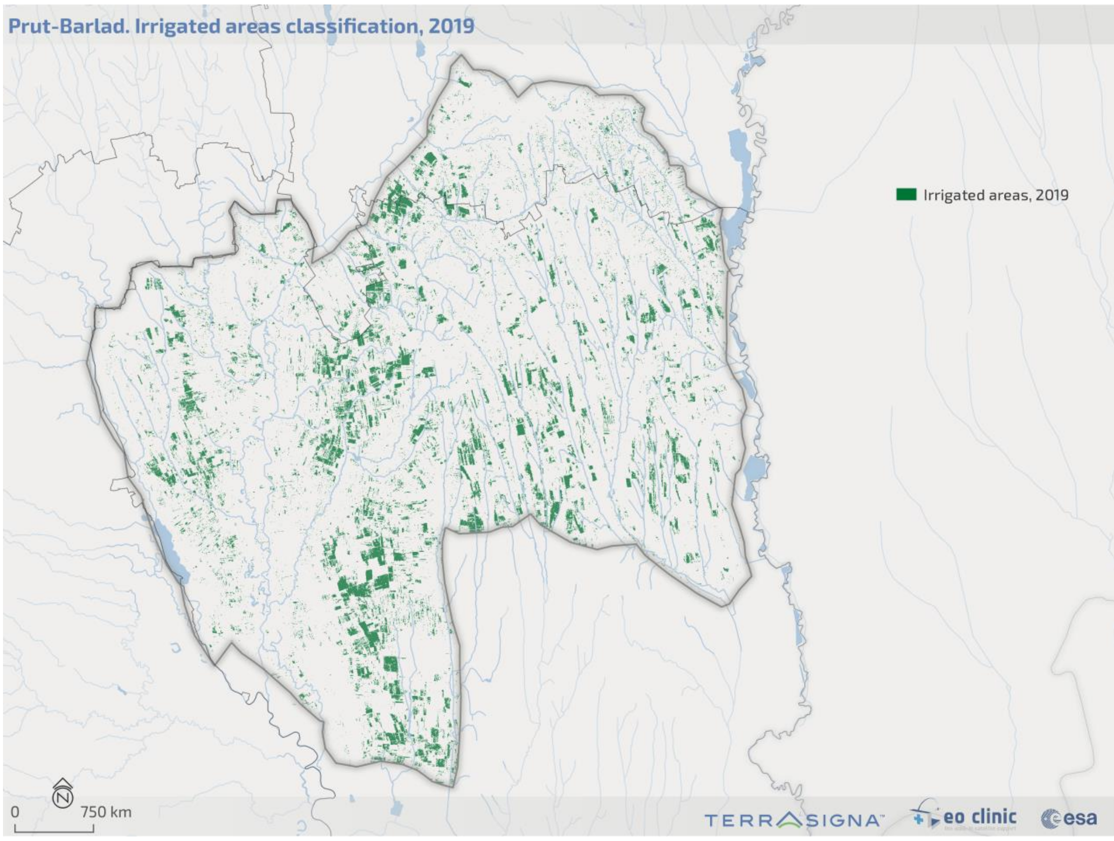


FIGURE 20: Prut-Bârlad. Irrigated areas classification, 2019

Regarding irrigated crops (Fig. 21, Fig. 22, Table 19), a dominance of autumn crops can be observed, again. Maize and sunflower, crops that usually need water within the summer months, cover about 80% of all irrigated crops.

The main irrigated autumn crops are wheat and barley, for which usually the duration of the winter season and its effect on soil moisture content dictate the need for irrigation, totalling about 17% of the total irrigated crops.

In addition to the mentioned crops, there can also be observed traditionally irrigated crops, such as beet (almost 40% irrigated within the crop class) or soybean (almost 45% irrigated within the crop class).

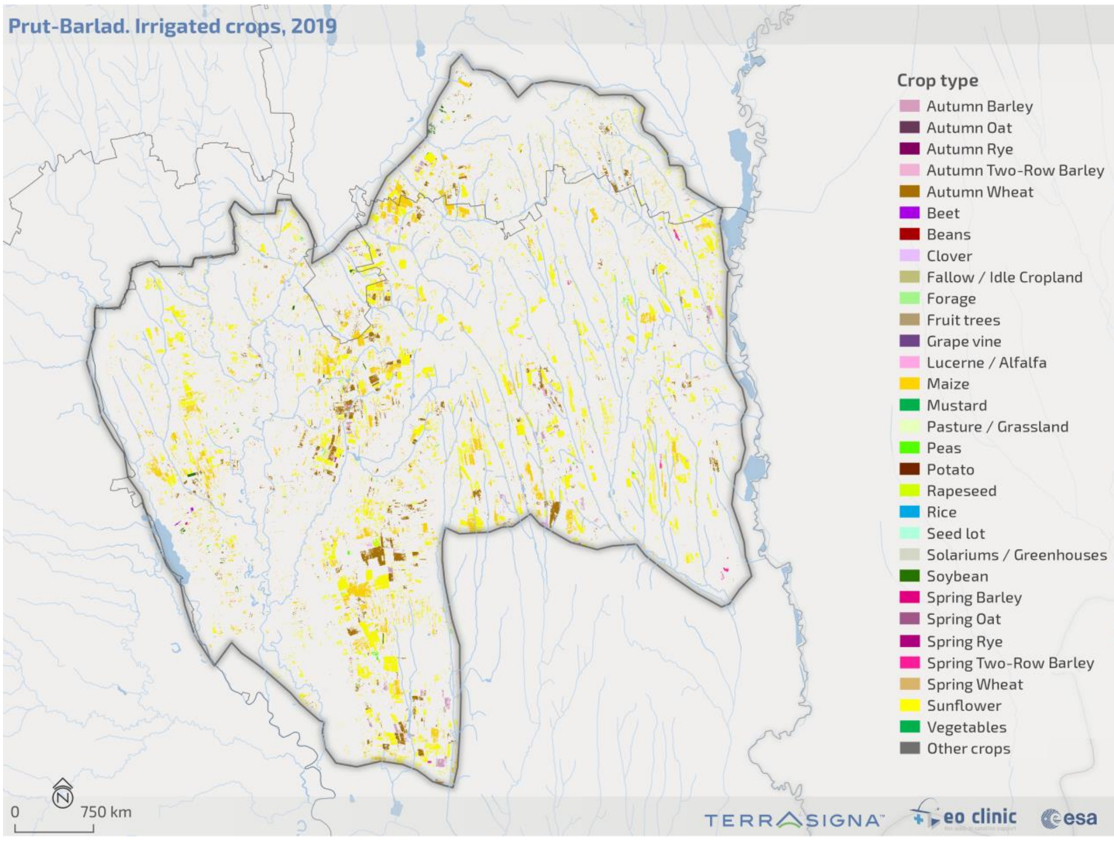


FIGURE 21: Prut-Bârlad. Irrigated crops, 2019

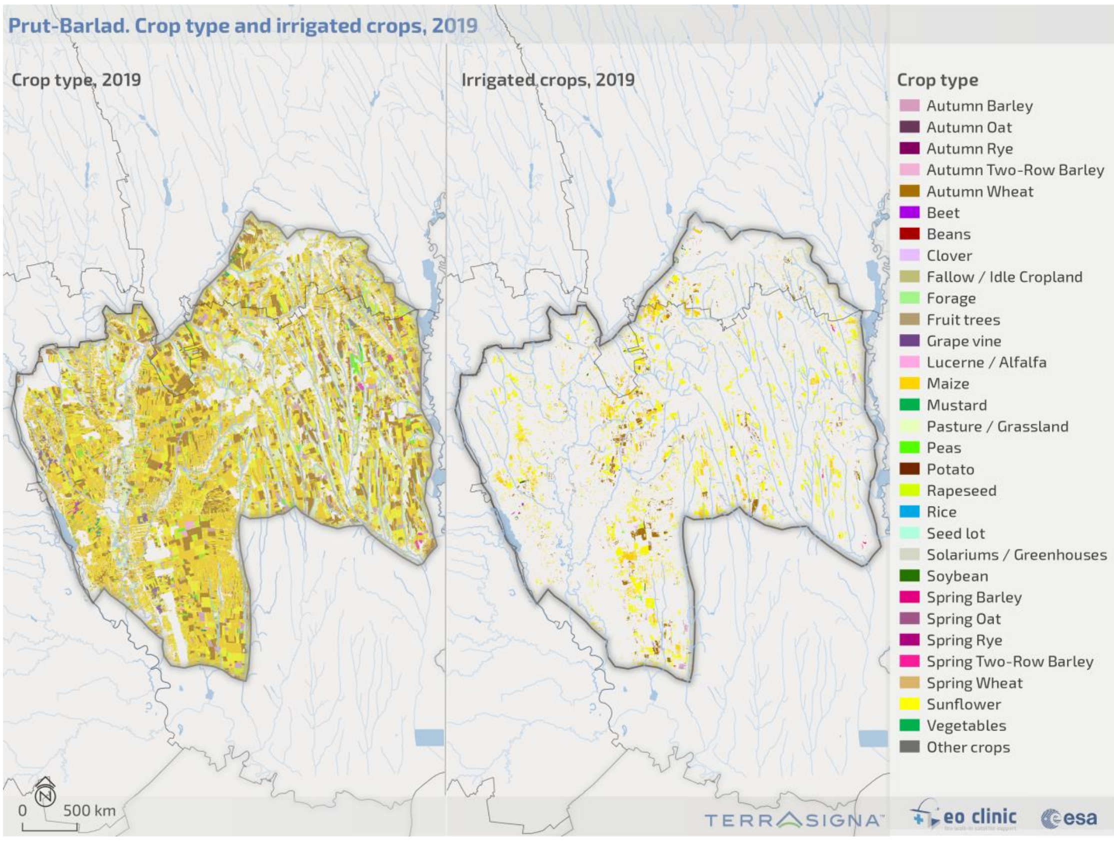


FIGURE 22: Prut-Bârlad. Crop type map versus irrigated crop type map, 2019

TABLE 19: Prut-Bârlad. Crop classes (2019) and irrigated areas

Crop Class	Total surface covered (ha)	Percentage of AOI's agricultural land (%)	Irrigated surface (ha)	Percentage of irrigated surface within the crop class (%)	Percentage of total irrigated crops (%)
Autumn Barley	4988.72	2.17	838.65	16.81	3.09
Autumn Oat	62.33	0.03	1.1	1.76	0.00
Autumn Rye	13.64	0.01	0.01	0.07	0.00
Autumn Two-Row Barley	72.98	0.03	31.83	43.61	0.12
Autumn Wheat	39502.06	17.16	3903.05	9.88	14.40
Beans	147.31	0.06	5.4	3.67	0.02
Beet	45.18	0.02	17.8	39.40	0.07
Fallow / Idle Cropland	205.13	0.09	3.21	1.56	0.01
Forage	1143.57	0.50	20.55	1.80	0.08
Fruit trees	208	0.09	0.27	0.13	0.00
Grape vine	1264.61	0.55	2.23	0.18	0.01
Lucerne/Alfalfa	4934.84	2.14	288.73	5.85	1.07
Maize	87780.05	38.12	7949.71	9.06	29.33
Mustard	157.43	0.07	2.58	1.64	0.01
Pasture/Grassland	33952.64	14.75	364.44	1.07	1.34
Peas	2860.04	1.24	181.65	6.35	0.67
Potato	9.88	0.00	0.52	5.26	0.00
Rapeseed	3749.31	1.63	110.43	2.95	0.41
Rice	0.71	0.00	0.02	2.82	0.00
Seed lot	39.13	0.02	1.43	3.65	0.01
Solariums / Greenhouses	439.17	0.19	-	-	-
Soybean	377.57	0.16	169.58	44.91	0.63
Spring Barley	167.65	0.07	17.31	10.33	0.06
Spring Oat	270.1	0.12	7.92	2.93	0.03
Spring Two-Row Barley	1018.47	0.44	106.19	10.43	0.39
Spring Wheat	65.78	0.03	14.87	22.61	0.05
Sunflower	44498.42	19.33	13005.01	29.23	47.99
Vegetables	807.19	0.35	15.05	1.86	0.06
Other crops	1464.78	0.64	17.7	1.21	0.07

3.1.2.3 AOI3 – Arad-Timiș. Mapping of irrigated areas, 2019

The third AOI analysed (Fig. 23) is located in the western part of the country and presents different climatic patterns compared to the first two, with average annual rainfall between 550-600 mm and western climatic influences.

The crop type map produced by TERRASIGNA (Fig. 24, Fig. 25, Table 20) indicates that autumn wheat dominates the agricultural landscape (over 200 000 ha, summing more than 36% of the surface of the AOI), followed by maize (almost 143 000 ha, summing more than 26% of the surface of the AOI) and pasture/grassland (almost 65 000 ha, summing almost 12% of the surface of the AOI). Other important cultivated crop classes are sunflower (over 10% of the surface of the AOI), rapeseed (almost 5% of the surface of the AOI) and autumn barley (almost 2.5% of the surface of the AOI).

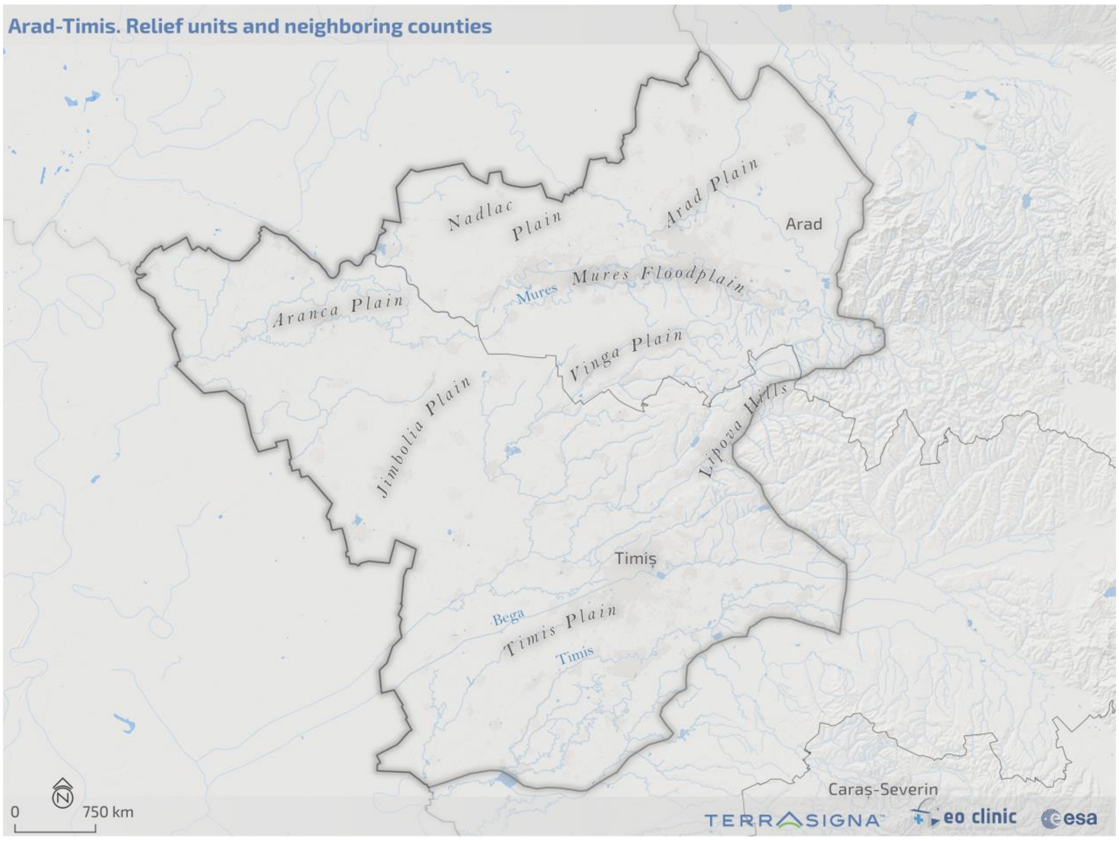


FIGURE 23: Arad-Timiș. Relief units and neighbouring counties

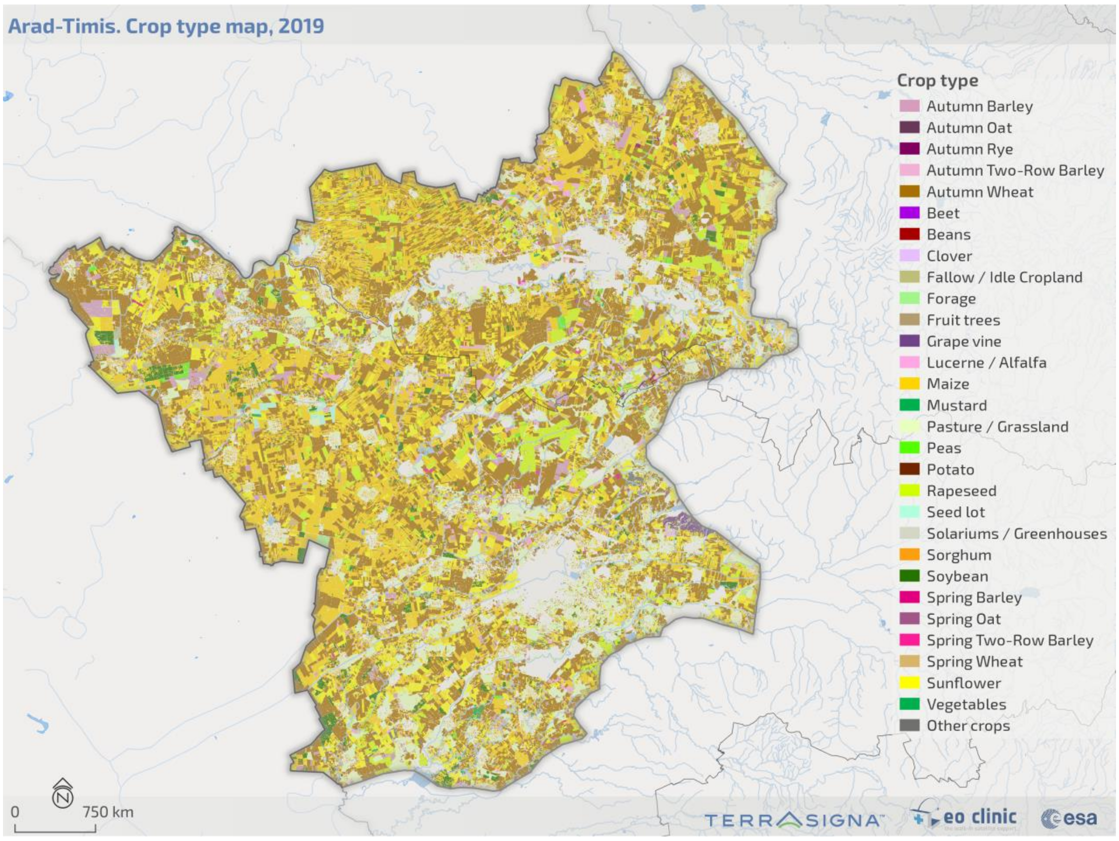


FIGURE 24: Arad-Timiş. Crop type map, 2019

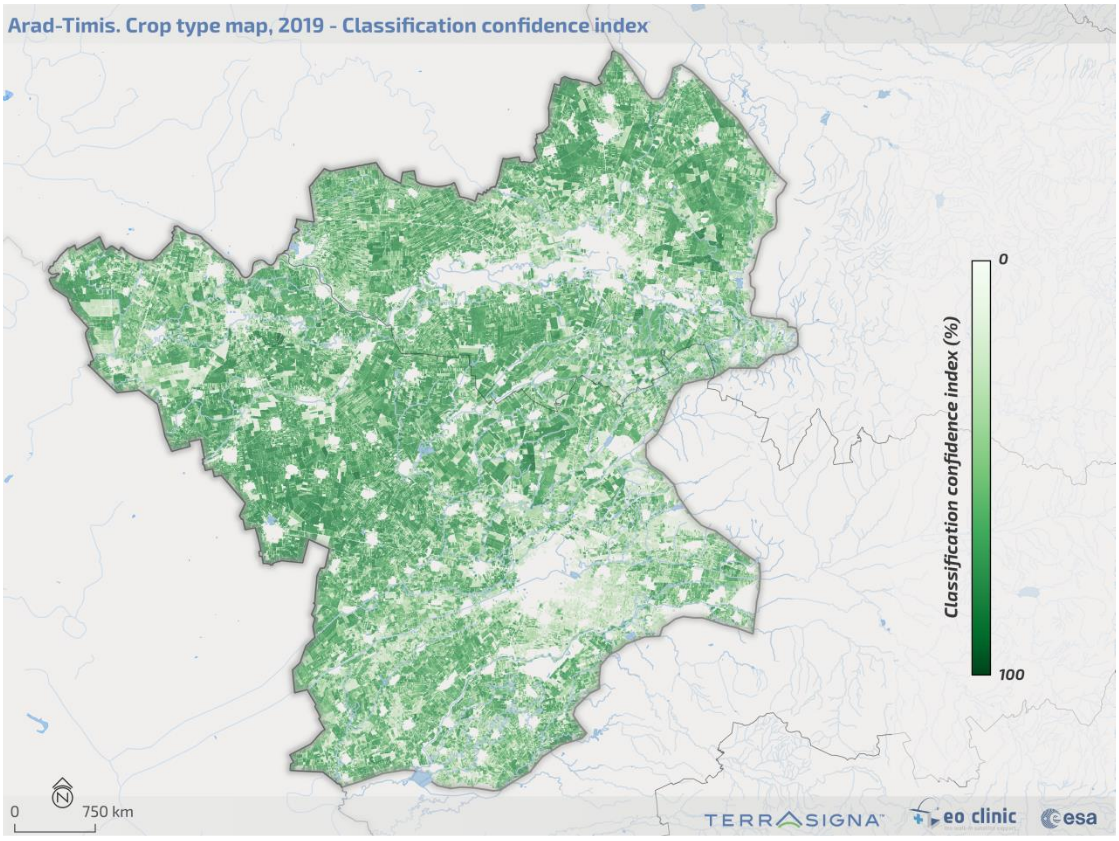


FIGURE 25: Arad-Timiş. Classification confidence index corresponding to the crop type map, 2019

TABLE 20: Arad-Timiş. Crop classes (2019) and areas covered

Crop Class	Area (ha)	Percentage (%)
Autumn Barley	12965.32	2.37
Autumn Oat	205.83	0.04
Autumn Rye	154.36	0.03
Autumn Two-Row Barley	1694.58	0.31
Autumn Wheat	201475.28	36.81
Beans	20.11	0.00
Beet	12.43	0.00
Clover	866.26	0.16
Fallow / Idle Cropland	1532.38	0.28
Forage	1136.85	0.21
Fruit trees	321.14	0.06
Grape vine	1008.16	0.18
Lucerne/Alfalfa	10376.33	1.90
Maize	142944.19	26.12
Mustard	593.03	0.11
Pasture/Grassland	64816.63	11.84
Peas	2023.84	0.37
Potato	110.15	0.02
Rapeseed	26541.14	4.85
Seed lot	1145.78	0.21
Solariums / Greenhouses	37.05	0.01
Sorghum	10.64	0.00
Soybean	11451.65	2.09
Spring Barley	170.4	0.03
Spring Oat	719.74	0.13
Spring Two-Row Barley	633.95	0.12
Spring Wheat	2225.99	0.41
Sunflower	58757.75	10.74
Vegetables	1194.95	0.22
Other crops	2143.49	0.39
Total	*547289.4 ha*	

In terms of irrigated areas classification (Fig. 26), the AOI is considered to be the most viable area for irrigation arrangements from the western part of the country and according to INSSE, in 2019 Arad and Timiş had the largest areas of land occupied by irrigation arrangements among the rest of the counties located in the west region of Romania. The irrigated areas cover 79 350 hectares, corresponding to more than 12% of the AOI and 14.5% of the agricultural area of the AOI.

Within the irrigated areas, there can be observed a consolidation tendency in Arad Plain, in the northern part of AOI, and Jimbolia Plain, in the western part, with compact areas and large irrigated plots, belonging to the big agricultural holdings.

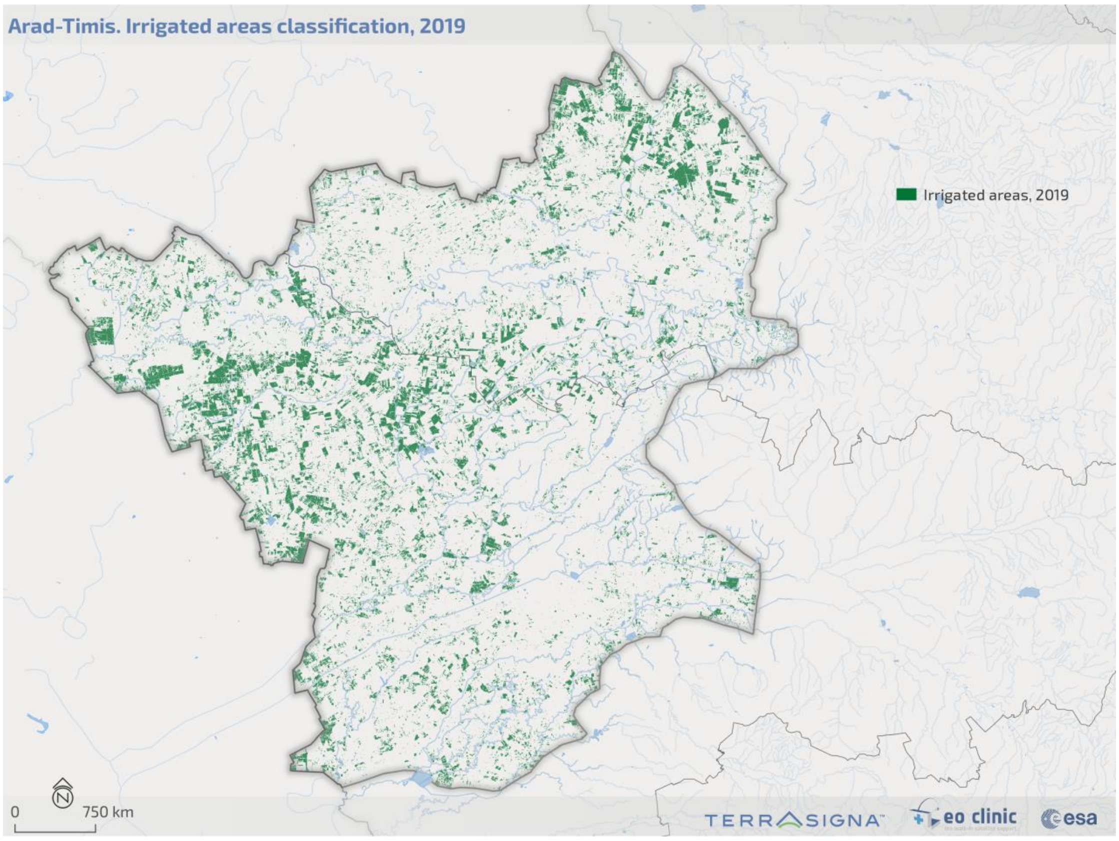


FIGURE 26: Arad-Timiş. Irrigated area classification, 2019

Regarding irrigated crops (Fig. 27, Fig. 28, Table 21), 3 spring crop classes cover 90% of total irrigated crops: maize (almost 47% of total irrigated crops), sunflower (almost 33% of total irrigated crops) and soybean (more than 10% of total irrigated crops), while autumn crops have insignificant percentages (e.g. autumn wheat - 2.8% of total irrigated crops), due to the climate with western, oceanic influences and abundant spring precipitation, so that most autumn crops do not require irrigation.

Within the crop classes, the presence of some traditionally cultivated irrigated classes is noticeable, such as soybean (almost 74% irrigated within the crop class), beet (23% irrigated within the crop class), lucerne / alfalfa (21% irrigated within the crop class) and, of course, maize (26% irrigated within the crop class) and sunflower (44% irrigated within the crop class).

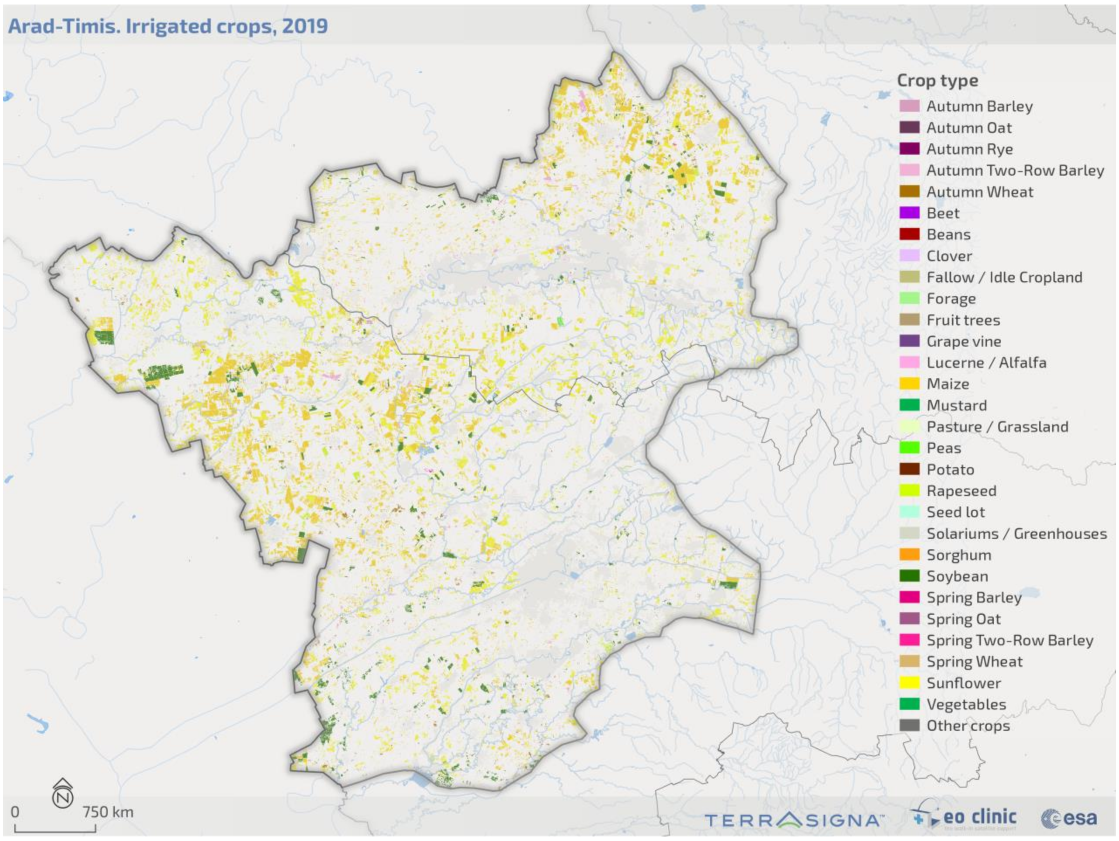


FIGURE 27: Arad-Timiş. Irrigated crops, 2019

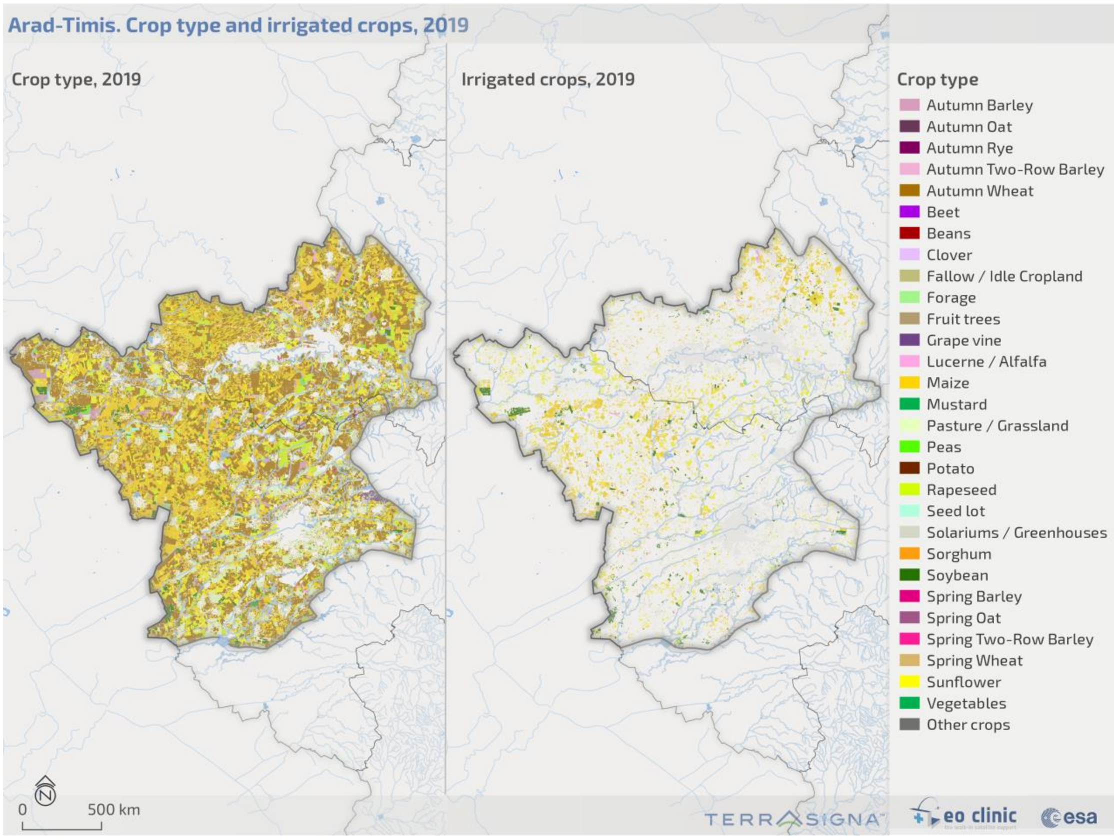


FIGURE 28: Arad-Timiş. Crop type map versus irrigated crop type map, 2019

TABLE 21: Arad-Timiş. Crop classes (2019) and irrigated areas

Crop Class	Total surface covered (ha)	Percentage of AOI's agricultural land (%)	Irrigated surface (ha)	Percentage of irrigated surface within the crop class (%)	Percentage of total irrigated crops (%)
Autumn Barley	12965.32	2.37	323.12	2.49	0.41
Autumn Oat	205.83	0.04	10.15	4.93	0.01
Autumn Rye	154.36	0.03	1.03	0.67	0.00
Autumn Two-Row Barley	1694.58	0.31	14.66	0.87	0.02
Autumn Wheat	201475.28	36.81	2220.35	1.10	2.80
Beans	20.11	0.00	0.51	2.54	0.00
Beet	12.43	0.00	2.87	23.09	0.00
Clover	866.26	0.16	27.83	3.21	0.04
Fallow / Idle Cropland	1532.38	0.28	16.18	1.06	0.02
Forage	1136.85	0.21	3.99	0.35	0.01
Fruit trees	321.14	0.06	2.88	0.90	0.00
Grape vine	1008.16	0.18	1.72	0.17	0.00
Lucerne/Alfalfa	10376.33	1.90	2178.14	20.99	2.74
Maize	142944.19	26.12	37152.57	25.99	46.82
Mustard	593.03	0.11	13.91	2.35	0.02
Pasture/Grassland	64816.63	11.84	1325.03	2.04	1.67
Peas	2023.84	0.37	161.40	7.97	0.20
Potato	110.15	0.02	7.51	6.82	0.01
Rapeseed	26541.14	4.85	1263.46	4.76	1.59
Seed lot	1145.78	0.21	2.42	0.21	0.00
Solariums / Greenhouses	37.05	0.01	-	-	-
Sorghum	10.64	0.00	0.16	1.50	0.00
Soybean	11451.65	2.09	8435.44	73.66	10.63
Spring Barley	170.40	0.03	9.11	5.35	0.01
Spring Oat	719.74	0.13	52.94	7.36	0.07
Spring Two-Row Barley	633.95	0.12	47.88	7.55	0.06
Spring Wheat	2225.99	0.41	40.03	1.80	0.05
Sunflower	58757.75	10.74	25921.27	44.12	32.67
Vegetables	1194.95	0.22	45.67	3.82	0.06
Other crops	2143.49	0.39	67.58	3.15	0.09

3.1.3 Quality Control and Validation

Crop type maps have been validated internally, using groud truth data, geotagged photos, as well as very-high-resolution imagery. The validation of results against independent sources revealed accuracies higher than 90% for more than 10 crop types.

Irrigated areas classifications have been validated visually, but also through statistical data, consisting in data regarding the total surface equipped with irrigation facilities and total irrigated area (at least one watering), provided for each county by INSSE. For example, according to INSSE, 140 615 ha of agricultural land were irrigated in Brăila in the 2019 agricultural season, while the areas identified by TERRASIGNA's algorithms total 134 638 ha.

What is more, the areas classified as being irrigated have also been compared to the ancillary geospatial data consisting in the spatial distribution of irrigation canals across the three AOIs.

3.2 Quantifying Irrigation Suitability. Multi-Criteria Assessment Analysis

The second category of products is represented by quantification of irrigation suitability within the three selected AOIs.

3.2.1 Specifications

The products delivered within the Quantification of Irrigation Suitability task and their specifications are listed in Table 22.

All the geospatial products were delivered in the Romanian national projection (Stereo 70 – EPSG31700), according to the needs of the beneficiary. Each dataset is accompanied by an ISO standard compliant metadata file (xml format) with all relevant product details.

All the maps and charts are also delivered separately, as .png files.

All products are delivered through the client preferred channel and will remain available for download for at least 12 months following initial delivery.

TABLE 22: Products delivered within the Quantification of Irrigation Suitability task

Product	Count	Resolution	Format	Accuracy
MULTI-CRITERIA ASSESSMENT ANALYSIS				
MCA variables	1	-	XLS / CSV	-
Metadata files	1	-	XML	-
IDENTIFICATION AND MAPPING OF POTENTIAL IRRIGATION SITES				
Irrigation Suitability Index	1	Medium-resolution	GeoTIFF	-
Description of the identified locations	1	-	Table (CSV / XLS)	-
Report (including maps and charts)	1	-	DOCX / PDF (maps in PNG)	-
Metadata file	1	-	XML	-

3.2.2 Outputs

3.2.2.1 AOI1 – Brăila County. Quantifying Irrigation Suitability

3.2.2.1.1 AOI1 – Brăila County. Water Deficit

The first component of the Water Deficit Index, the Drought Severity Index (Fig. 29), calculated for a period of 5 years (2015-2019) constantly presents medium and low values, falling under drier than normal conditions. The driest years are 2015 and 2019, also known in the literature for severe droughts in the area. Within the AOI, there are no clear patterns, and the 2015-2019 average shows a uniformity of the Drought Severity Index at the level of the entire Brăila county.

The second component, the Soil Water Index (Fig. 30), was also calculated for a period of 5 years (2015-2019). The pedological drought of 2019 led to extremely low values of this index. The years 2018 and 2015 are also distinguished by the pedological drought and low SWI values, with a clear differentiation between the Great Brăila Island and the rest of the county.

It should be noted that the central area of Brăila county shows the most accentuated trends of soil water deficit, a fact confirmed by the water availability analysis in the area.

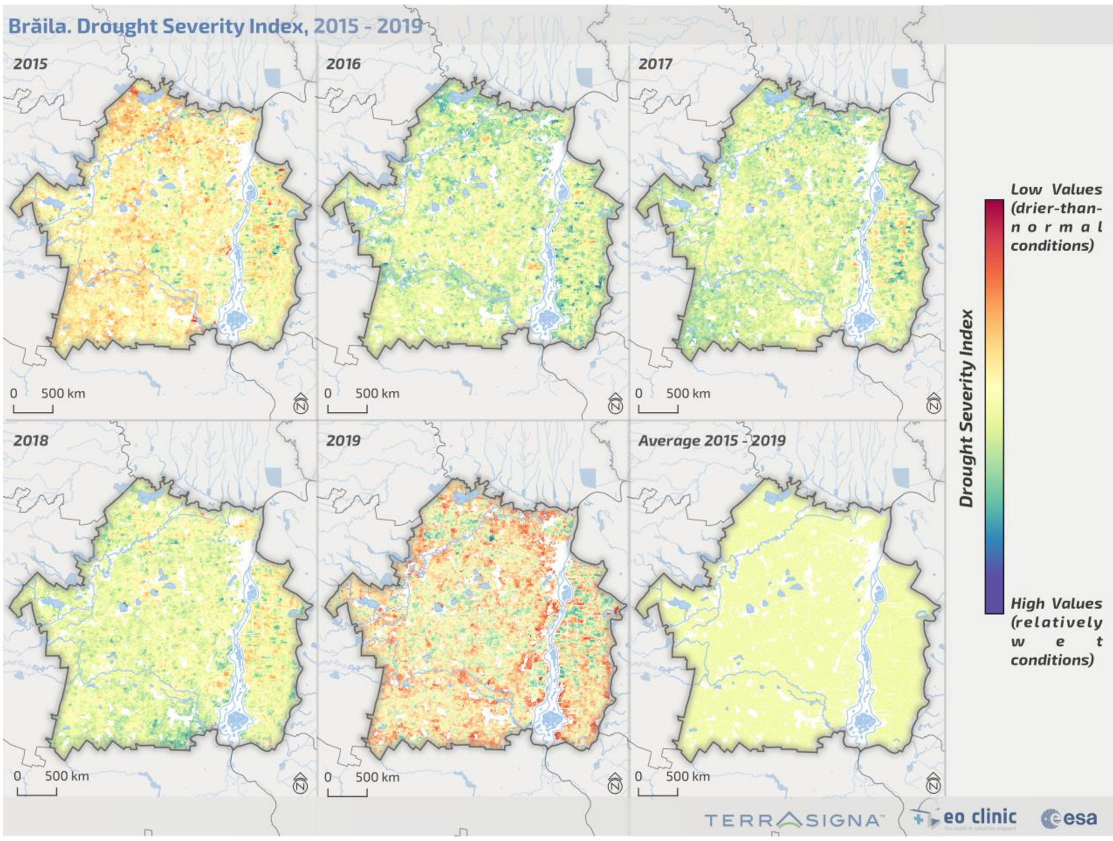


FIGURE 29: Brăila County. Drought Severity Index, 2015-2019

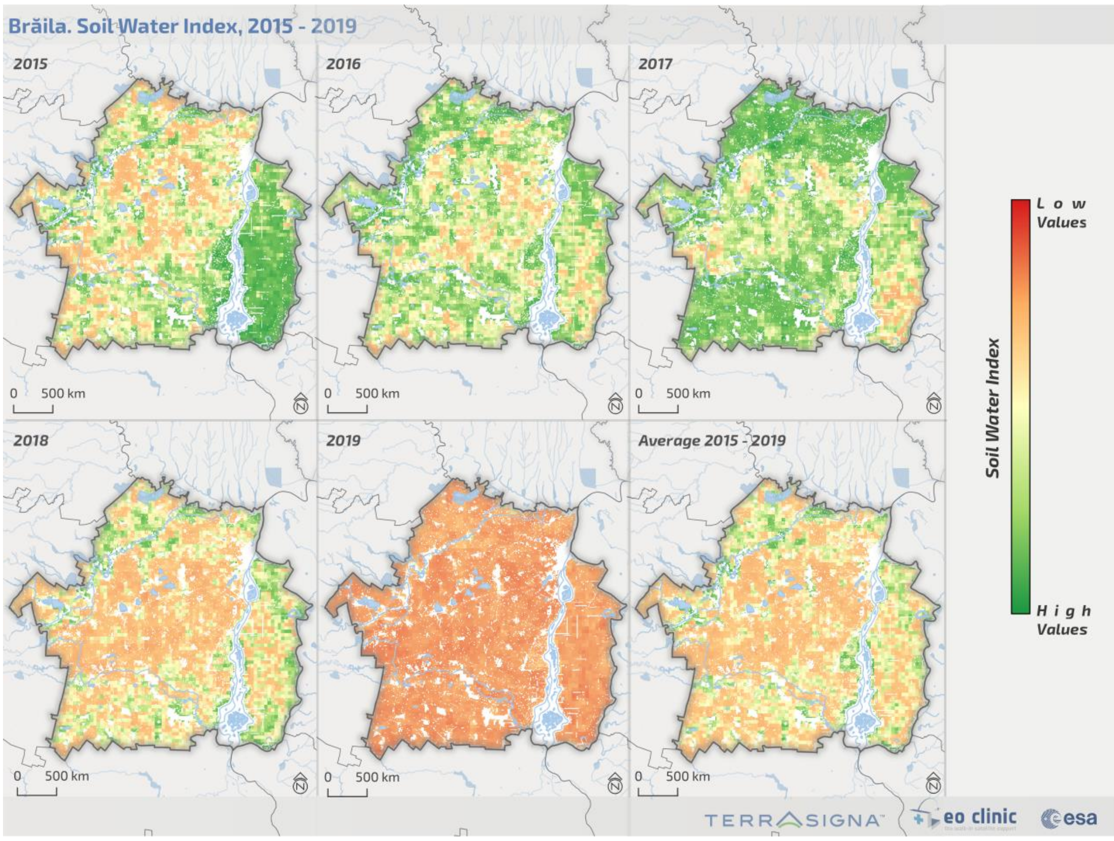


FIGURE 30: Brăila County. Soil Water Index, 2015-2019

The resulting Water deficit index (Fig. 31) does not show clear patterns, but the center of Brăila county and also the southern part of Great Brăila Island score higher in terms of water scarcity. A lower water deficit is noticeable in the north and center of the Big Island of Brăila, traditionally irrigated areas, belonging to a deeply artificial landscape.

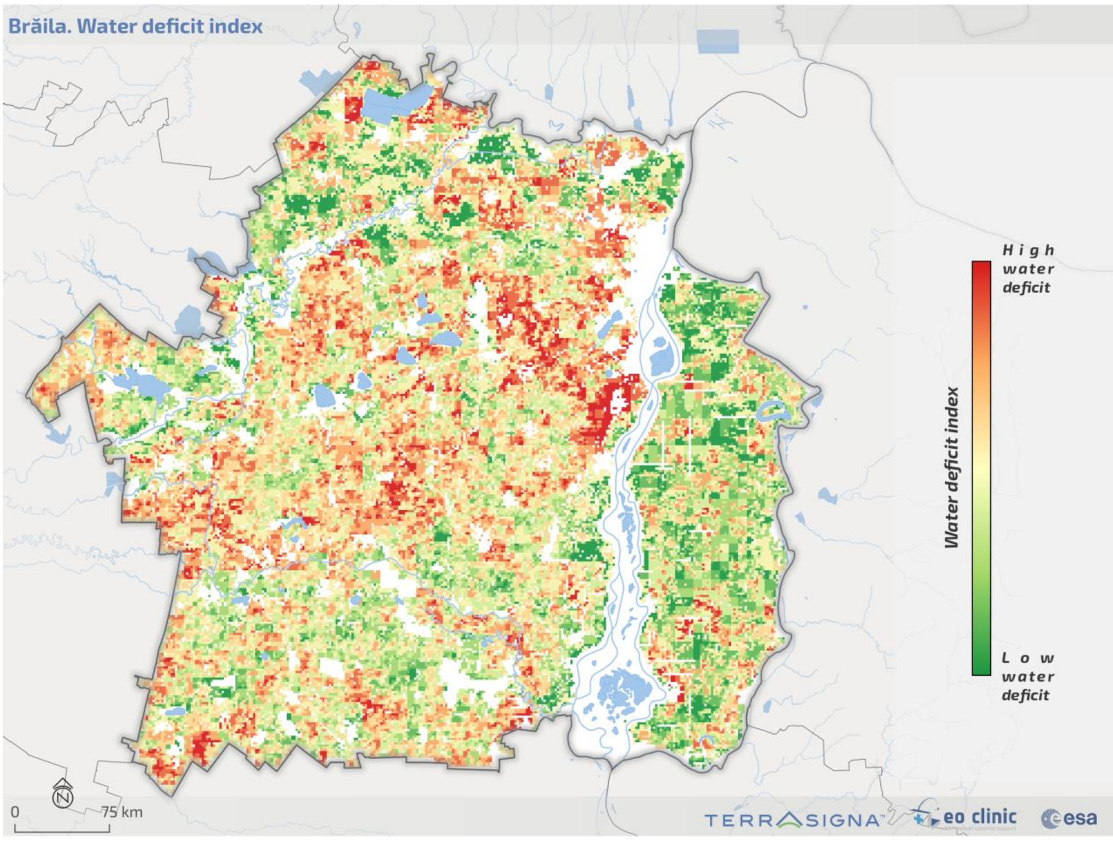


FIGURE 31: Brăila County. Water Deficit Index

3.2.2.1.2 AOI1 – Brăila County. Water Supply Potential

The Water Supply Potential Index was calculated based on four indicators (Fig. 32).

While the slope has relatively uniform and low values over the entire county, which falls exclusively in the plain relief, the Vertical Distance Index indicates certain least favorable areas in terms of irrigation, as the economic impact of water supply for irrigation would be major, by pumping water at significant altitudes relative to the main source of freshwater. Such areas are present in the south of the county, on the terraces of Călmățui River, in the Middle Baragan, but also in the central-western part, in the contact zone between Brăila Plain (North Baragan) and Buzău county / Buzău Plain and the higher Râmnic Plain.

The distance from freshwater sources also differentiates different patterns within the county. The areas located along the main valleys of the rivers Călmățui, Buzău and the Danube, but also in the southern part of Siret Floodplain, as well as the areas around the main lakes in the county are distinguished as favourable. However, it should be noted that the analysis integrated all the lakes in available in a geospatial format, downloaded from the ANCPI geoportal, part of Romania's topographic reference plan, corresponding to the scale 1: 50000 (TopR050). Thus, there is no distinction based on characteristics, lake origin or chemical composition, which can affect the irrigation process. There are large areas in the centre and south of the county located at distances greater than 5 km from freshwater sources, which affects the economic viability of the irrigation process.

Regarding the proximity to the irrigation infrastructure, Brăila county is known for the irrigation works covering extended areas, compared to the rest of the South-East region or the national level. The irrigation systems have a uniform coverage within the county, except for the contact area with Ramnicului Plain and the high terraces of the Călmățui river, according to the relief particularities. In order to increase the capitalization of the existing agricultural potential, it is further recommended to modernize the techniques and technologies used.

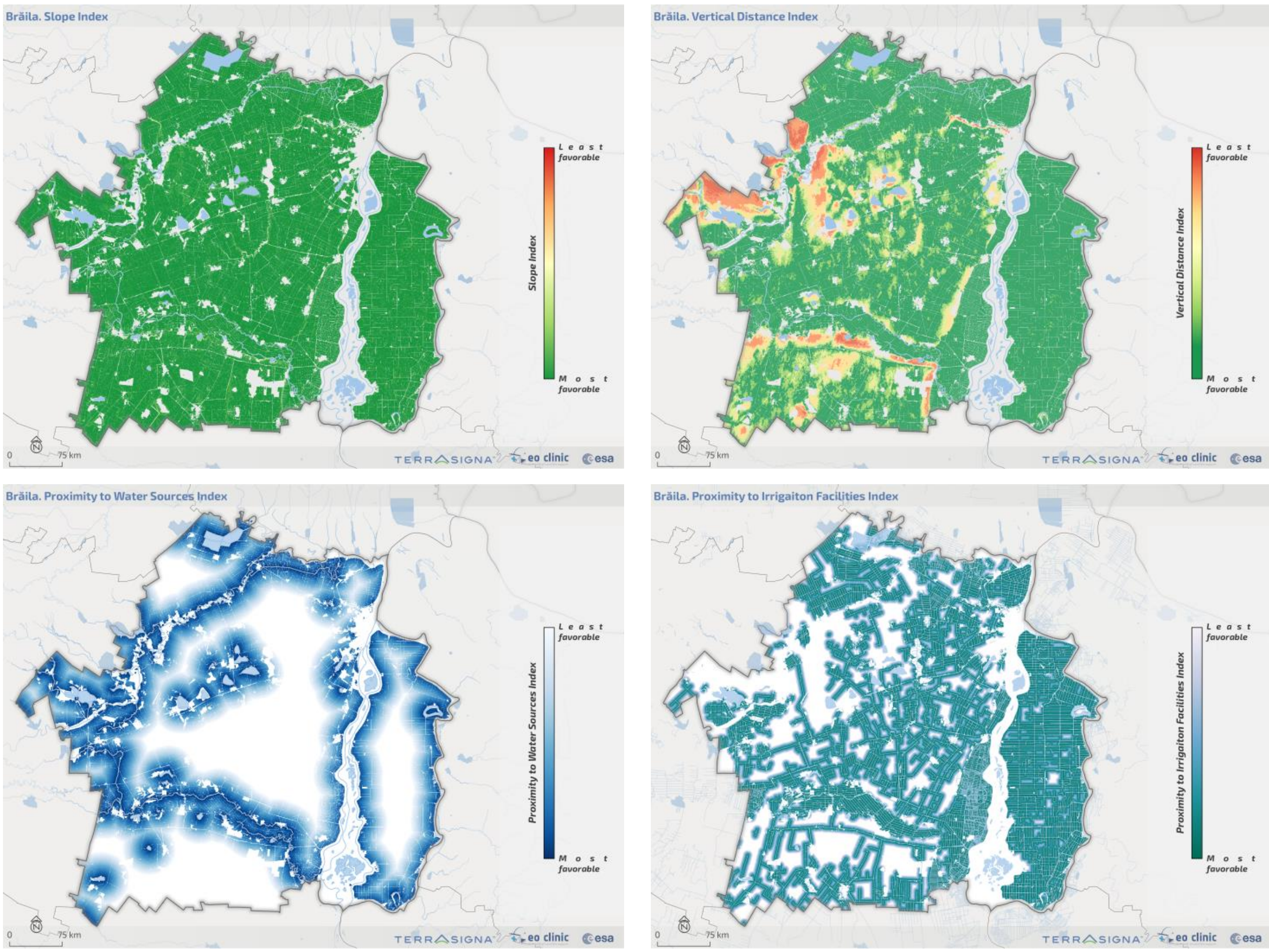


FIGURE 32: Brăila County. Water Supply Potential Indicators

The final index, Water Supply Potential Index (Fig. 33), indicates the surfaces along the main rivers as the main areas favourable for irrigation, while the central part of the county and the areas south of the Călmățui Valley have lower water supply potential.

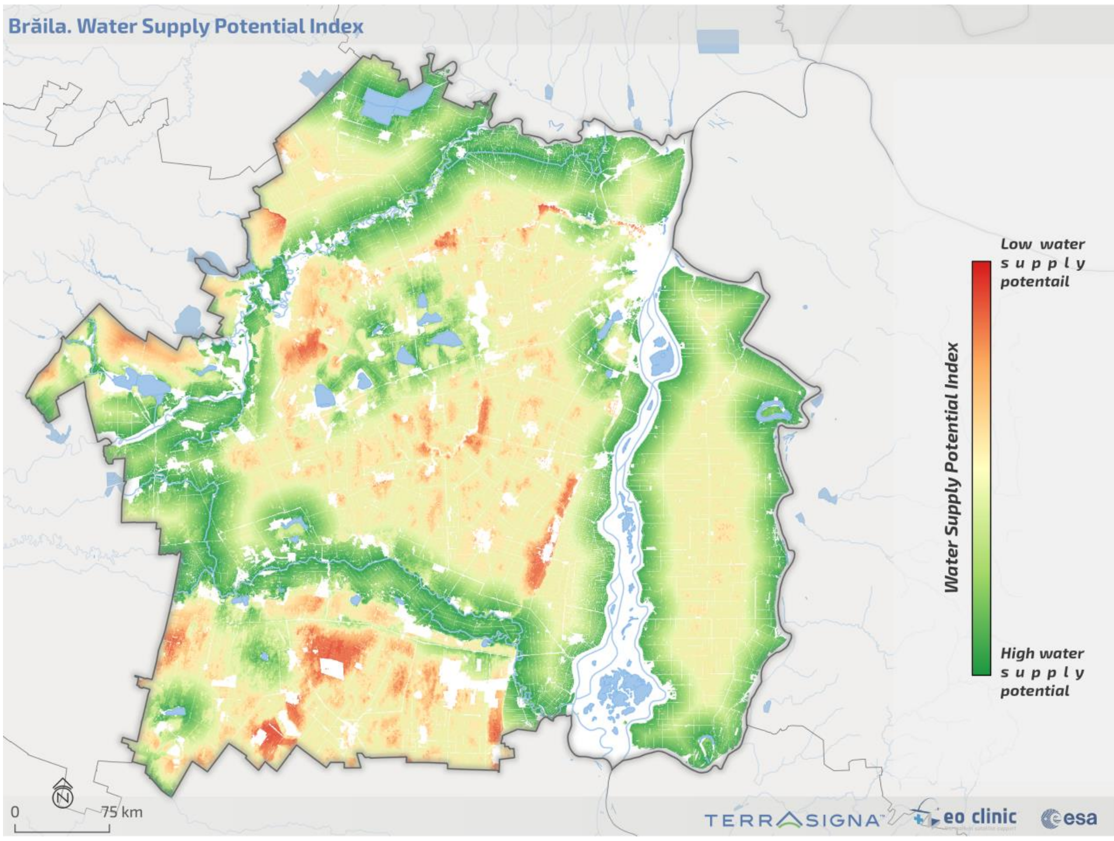


FIGURE 33: Brăila County. Water Supply Potential Final Index

3.2.2.1.3 AOI1 – Brăila County. Soil Irrigation Suitability

In terms of soil suitability for irrigation (Fig. 34), Brăila county presents, as a whole, favorable values for irrigation practice, most of the areas belonging to the Calcic Chernozem class, with medium and medium-fine textures. Most limitations for agriculture refer to excessively drained areas within the Calcaric Fluvisol class and are located along the Călmățui Valley. However, most of them are also characterized by the existence of water management systems to alleviate waterlogging (drainage). Other limitations for irrigation are given by the presence of a Sodic horizon (Na / T> 6% within 100 cm), especially in the salty areas around the lakes in the center of the county. The extremely fertile soils along the Danube and Buzău rivers correspond to the highest natural potential and soil irrigation suitability.

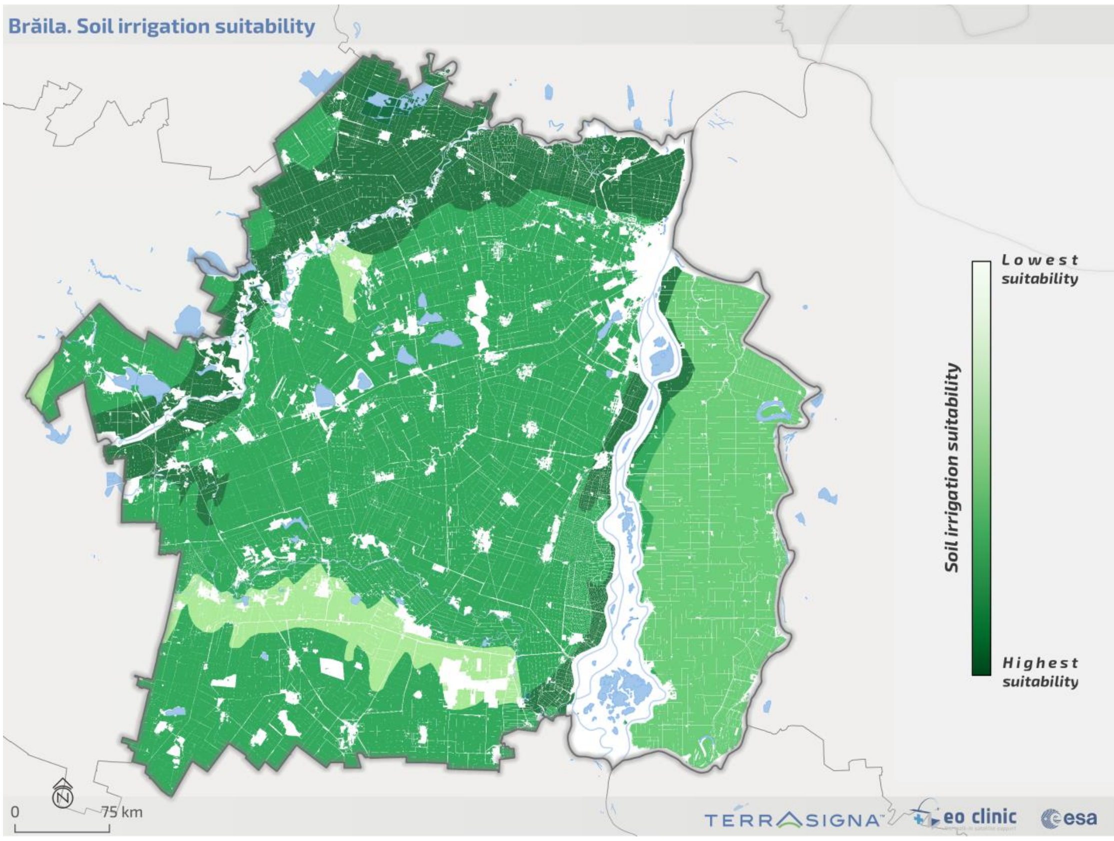


FIGURE 34: Brăila County. Soil irrigation suitability

3.2.2.2 AOI2 – Prut-Bârlad. Quantifying Irrigation Suitability

3.2.2.2.1 AOI2 – Prut-Bârlad. Water Deficit

The first component of the Water Deficit Index, the Drought Severity Index (Fig. 35), calculated for a period of 5 years (2015-2019) constantly presents medium and low values, falling under drier than normal conditions. There are strong drought conditions in 2015, as well as in 2019, especially in terms of its effects in the southern part of the area of interest, both in the areas along the Bârlad River Valley and in the Prut Floodplain. For the years 2016-2018, no clear patterns are noticed, while the multiannual average (5 years) indicates a uniformity at the level of the entire area, with medium-low values of the DSI, corresponding to drier than the normal conditions.

Regarding the Soil Water Index (Fig. 36), there can again be observed the major pedological drought of 2015 and 2019. In addition, certain regional patterns are identified - higher values of soil water content on the high terraces of the Western Tecuci Plain, located to the west of Bârlad Valley, but also in the northeast of the AOI, in the higher hilly area. At multiannual level, the analysed area presents, as a whole, low values of the Soil Water Index, the most affected area in terms of pedological drought being the Eastern Tecuci Plain.

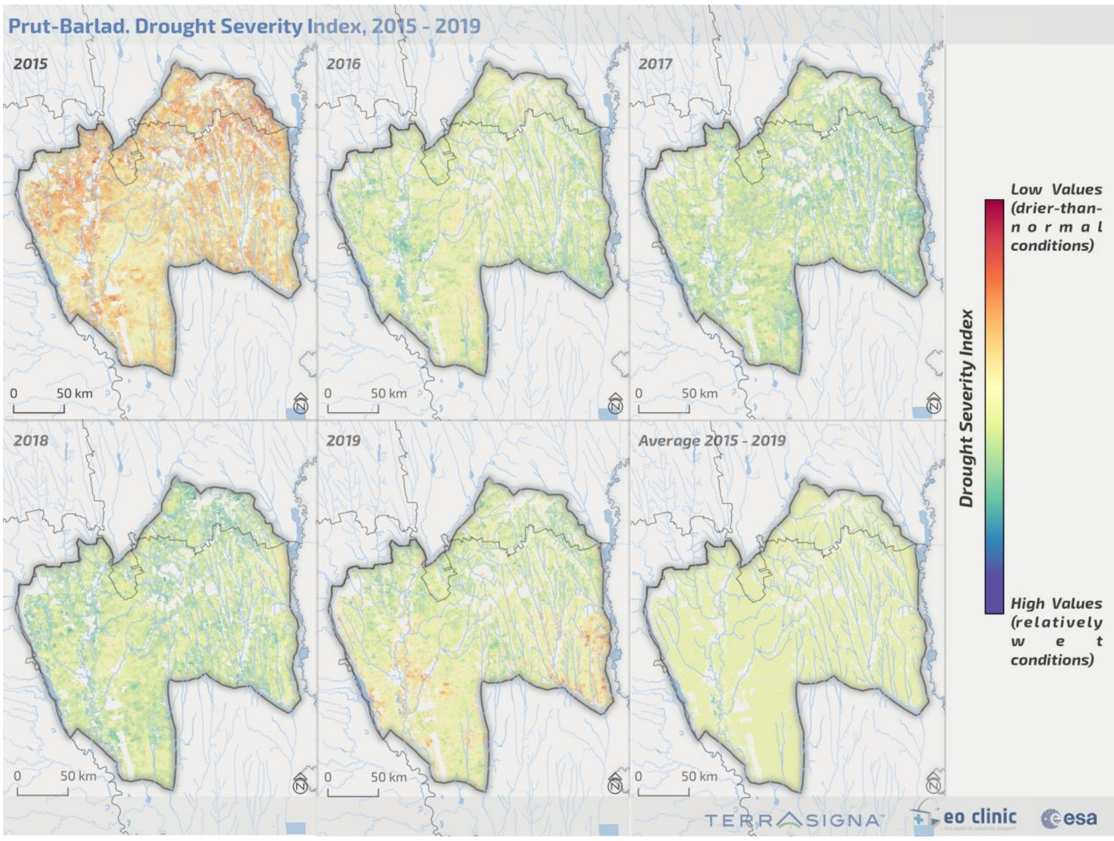


FIGURE 35: Prut-Bârlad. Drought Severity Index, 2015-2019

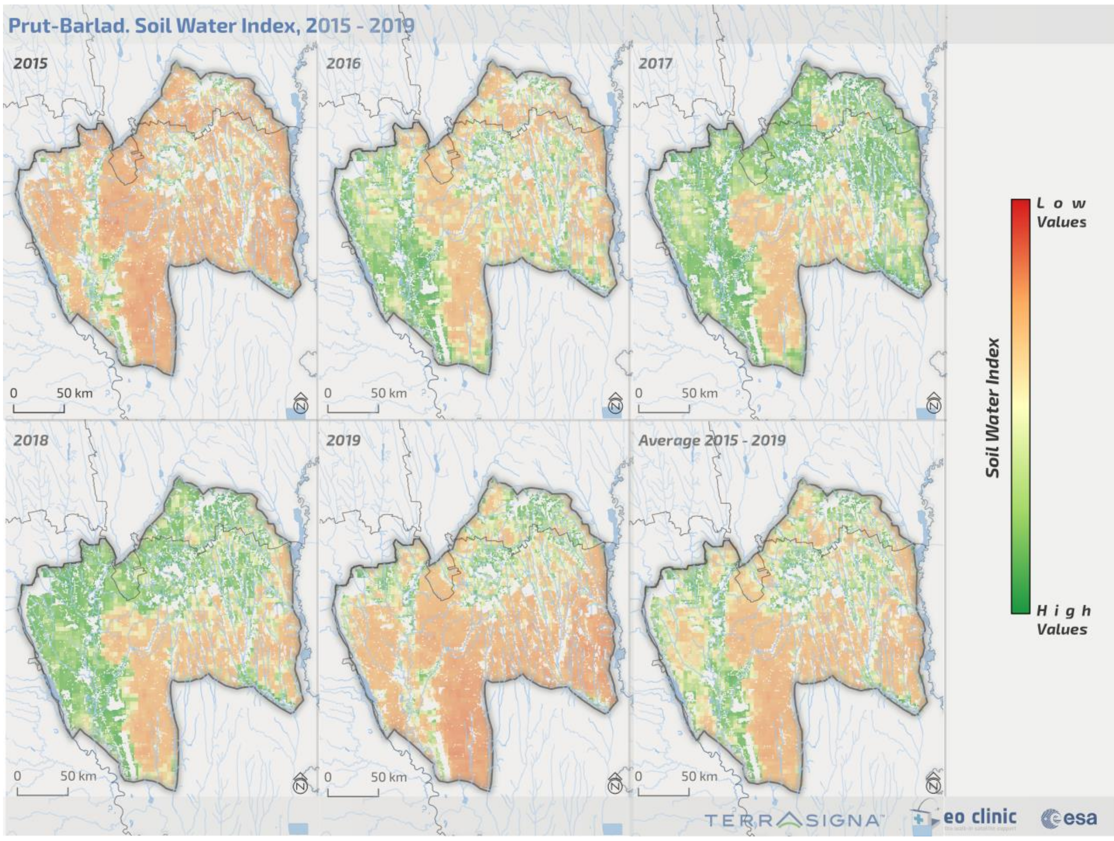


FIGURE 36: Prut-Bârlad. Soil Water Index, 2015-2019

The resulting Water deficit index (Fig. 37) shows clear patterns, with a high water deficit in the central-southern part, in the Eastern Tecuci Plain, east of Bârlad Valley, deficit which is increased by the presence of dunes developed on the sandy substrate, and in the eastern extremity of the area, in the contact area with Prut Floodplain, the areas being known for the frequent pedological droughts and the important insurance compensations required for the areas affected by the drought.

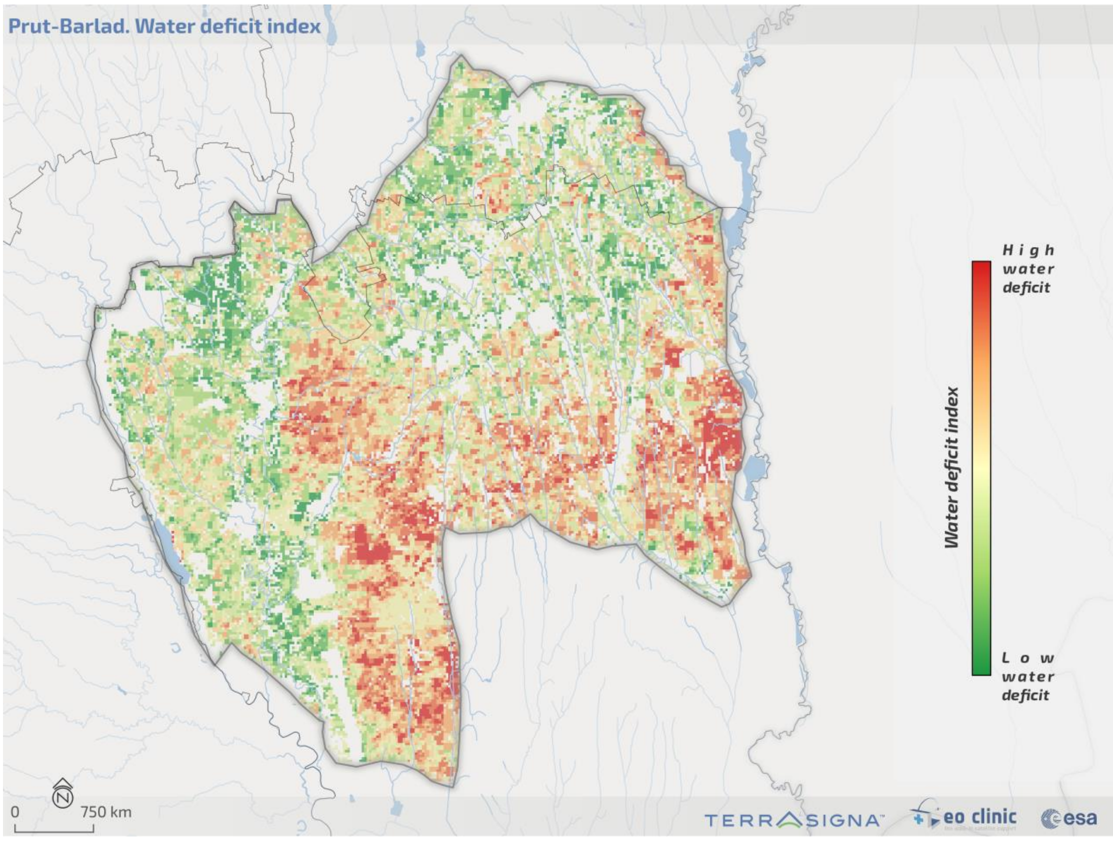


FIGURE 37: Prut-Bârlad. Water Deficit Index

3.2.2.2.2 AOI2 – Prut-Bârlad. Water Supply Potential

The Water Supply Potential Index was calculated based on four indicators (Fig. 38).

Slope, the first indicator taken into account in computing the Water Supply Index, shows different patterns in the western compared to the eastern part of the analysed area. While Tecuci Plain is relatively flat, with low slope values and high favourability for the development of irrigation systems, the eastern side of the AOI is much more fragmented, with a medium favourability in terms of water supply.

The Vertical Distance Index filters the results even more, expressing itself in terms of favourable areas on an area in the western part of the AOI, along the Bârlad Valley, as well as along the smaller valleys of the tributary rivers. The rest of the area presents less favourable conditions, for which the implementation of irrigation systems based mainly on canals would not be economically feasible.

Regarding the proximity to freshwater sources, the area has relatively homogeneous values, most of the surface being included in the buffer of 5km from water sources, except for the area developed on sandy substrate southeast of the city of Tecuci.

The irrigation infrastructure of the Prut-Bârlad AOI is quite dispersed, the main canals being located along the Bârlad River Valley, the Prut Valley and its tributaries. However, no information is available on the viability of these irrigation canals and their operating status.

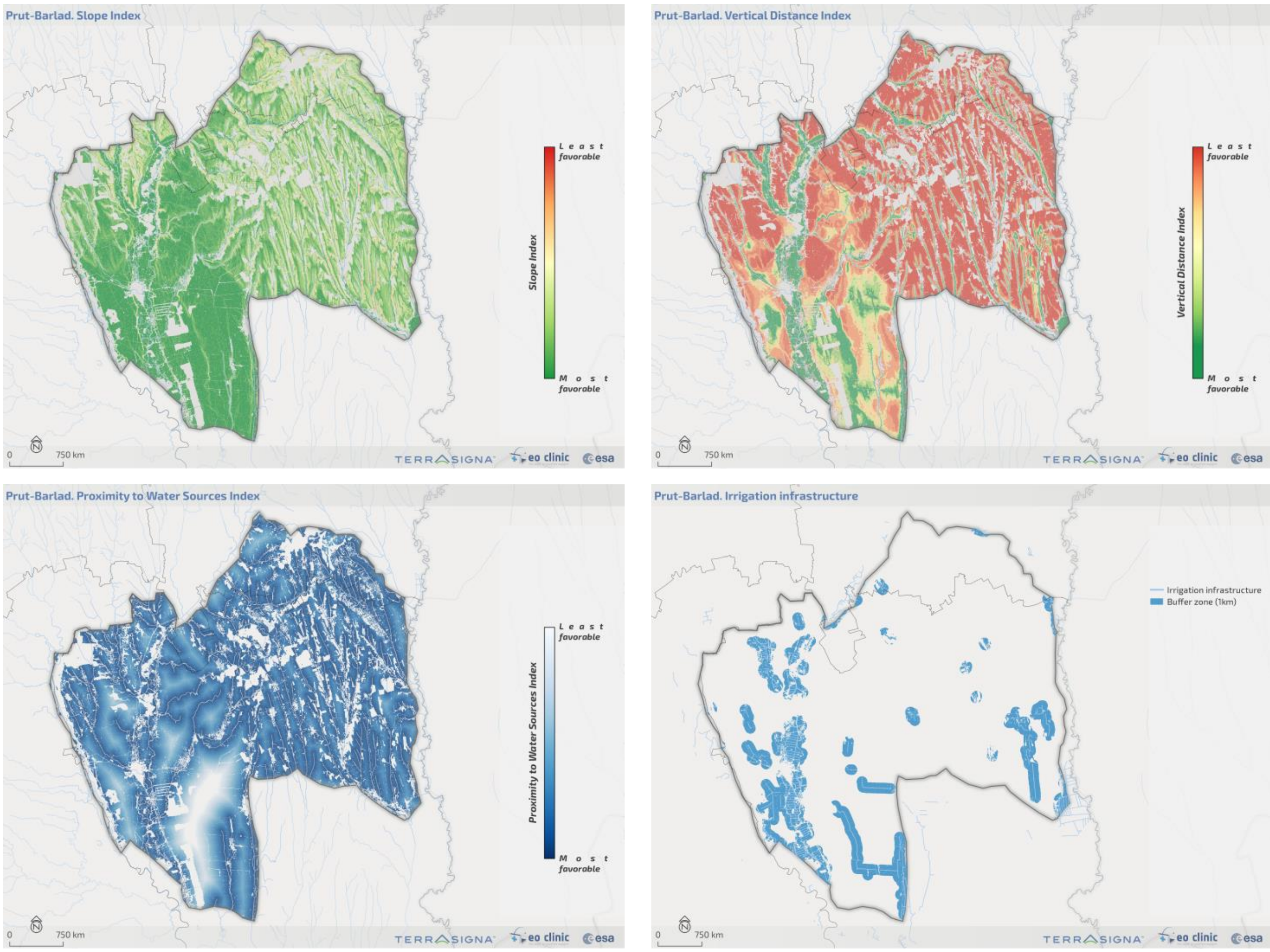


FIGURE 38: Prut-Bârlad. Water Supply Potential Indicators

The Water Supply Potential Index (Fig. 39) is characterized by overall low suitability, with the exception of the plain areas in the southwest of the area and the floodplain areas around the main rivers, especially along Bârlad river.

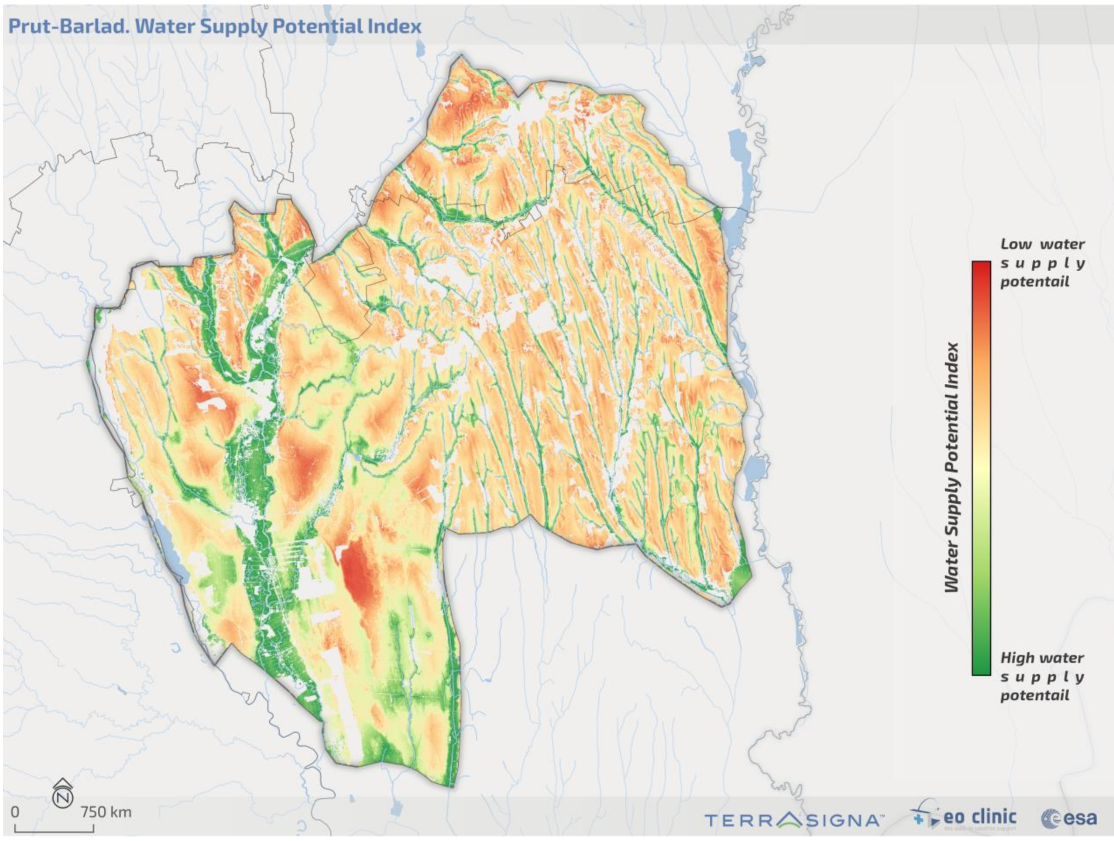


FIGURE 39: Prut-Bârlad. Water Supply Potential Final Index

3.2.2.2.3 AOI2 – Prut-Bârlad. Soil Irrigation Suitability

Soil irrigation suitability (Fig. 40) shows medium-high values in the majority of the surface of the AOI, with the highest suitability being registered in the area of the fertile terraces of Bârlad and Prut rivers. The main limitations for agricultural use are given by excessively drained areas of river floodplains. The areas characterized by the lowest suitability are those of the Luvic Arenosol class, characterized by coarse texture, respectively Haplic Greyzem, which present important limitations for irrigated agriculture.

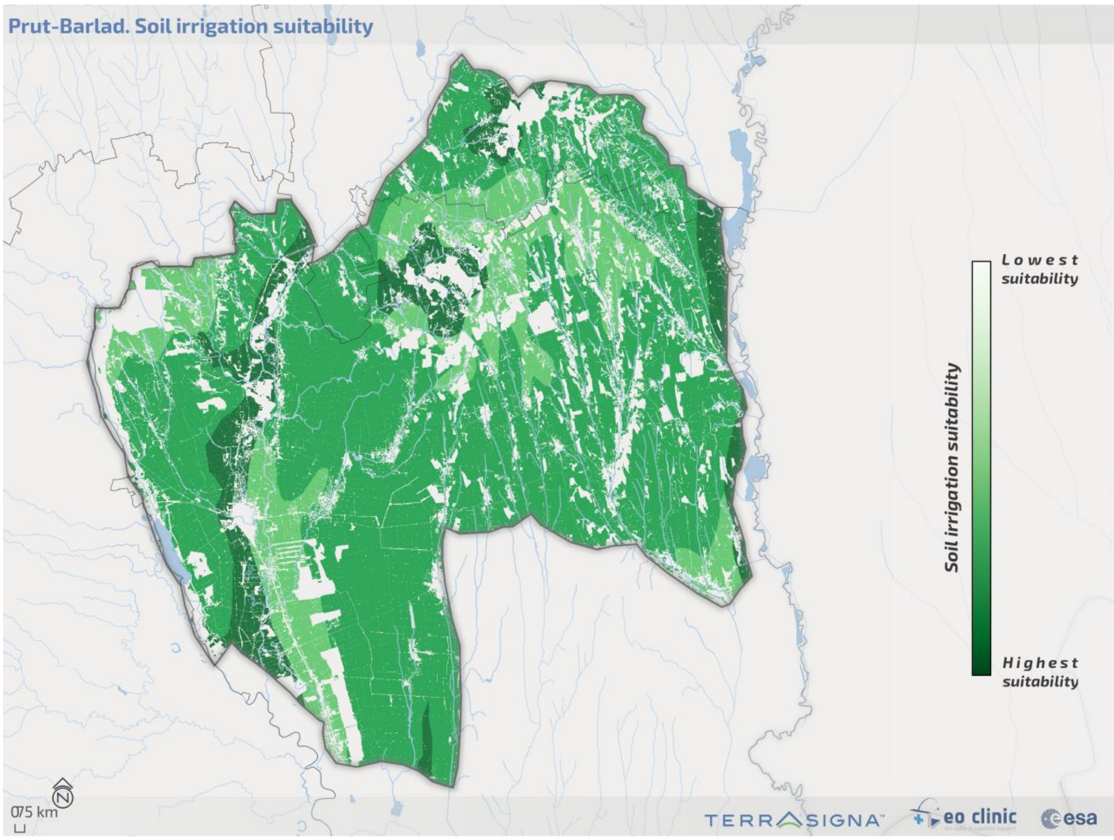


FIGURE 40: Prut-Bârlad. Soil irrigation suitability

3.2.2.3 AOI3 – Arad-Timiş. Quantifying Irrigation Suitability

3.2.2.3.1 AOI3 – Arad-Timiş. Water Deficit

The first component of the Water Deficit Index, the Drought Severity Index (Fig. 41), calculated for a period of 5 years (2015-2019) presents different patterns compared to the other two AOIs, due to the predominant western, oceanic climatic influences. While 2015 still stands out as a year with drier than normal conditions, 2017 is distinguished from the rest of the AOIs by the severe drought, especially in the Arad Plain and in the areas along the valleys of the Bega and Timiş rivers. The years 2016, 2018, 2019 are distinguished by medium-high values of the DSI and relatively wet conditions. The multiannual average presents a certain uniformity at the level of the entire area, falling within medium conditions.

The second indicator, the Soil Water Index (Fig. 42), confirms the pedological drought specific to 2015 and 2017, but medium-low values can also be observed for 2019. Overall, the multi-annual average of SWI indicates medium high values of the index, a completely different pattern compared to the other two AOIs analysed.

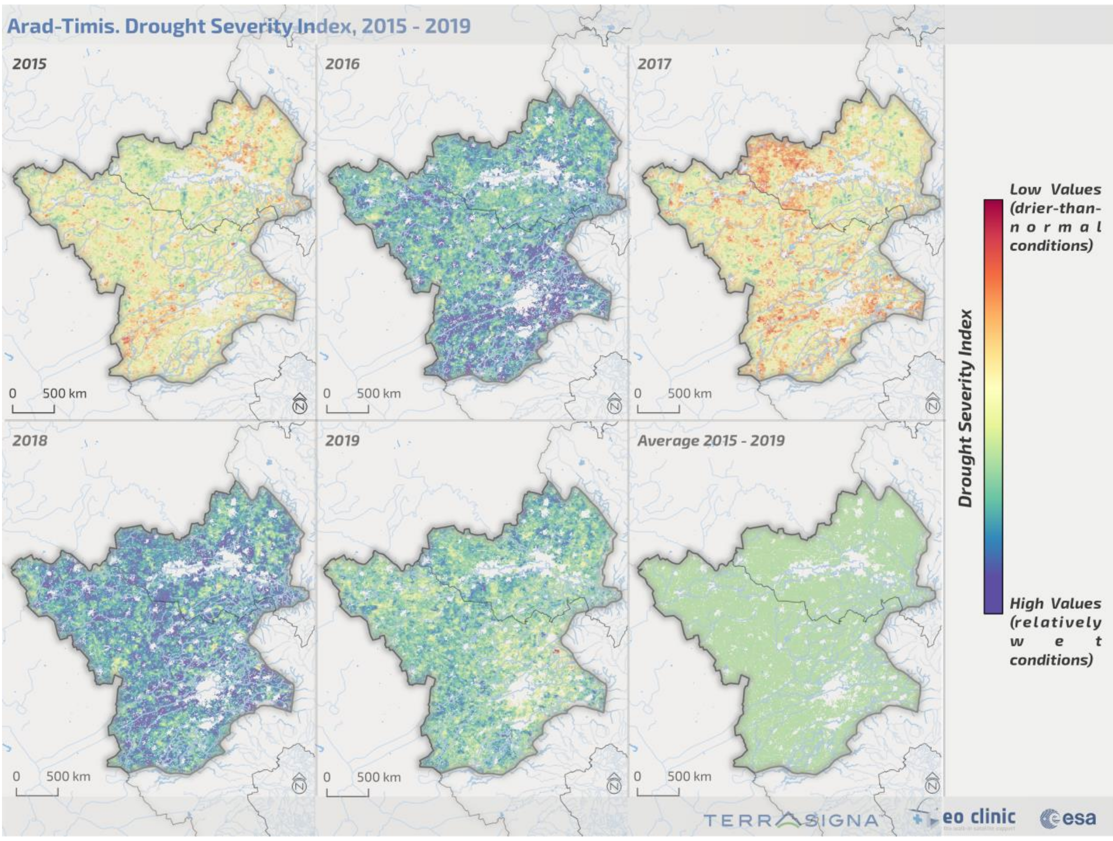


FIGURE 41: Arad-Timiş. Drought Severity Index, 2015-2019

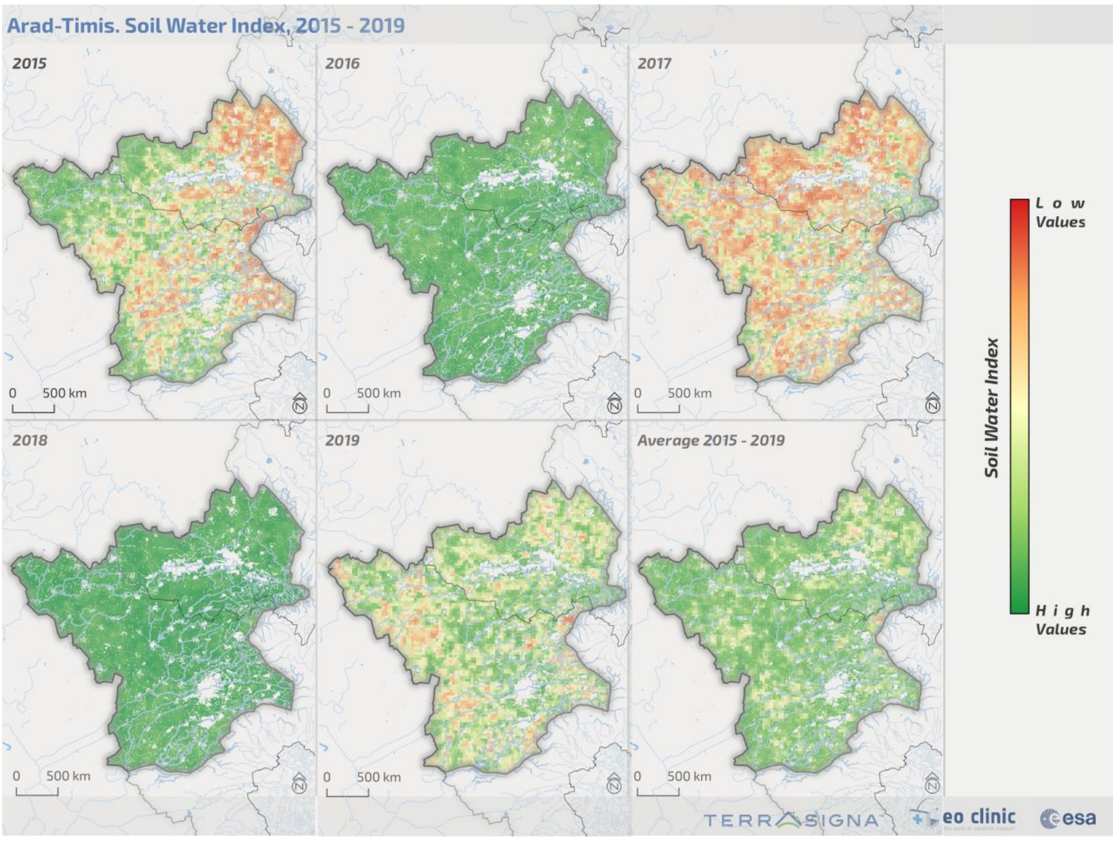


FIGURE 42: Arad-Timiş. Soil Water Index, 2015-2019

The combined Water Deficit Index (Fig. 43) is distinguished by high water deficit values in the northern part of the AOI, in the tabular plain of Arad, but also regional patterns in the Vinga Plain and the east of the Timiş Plain.

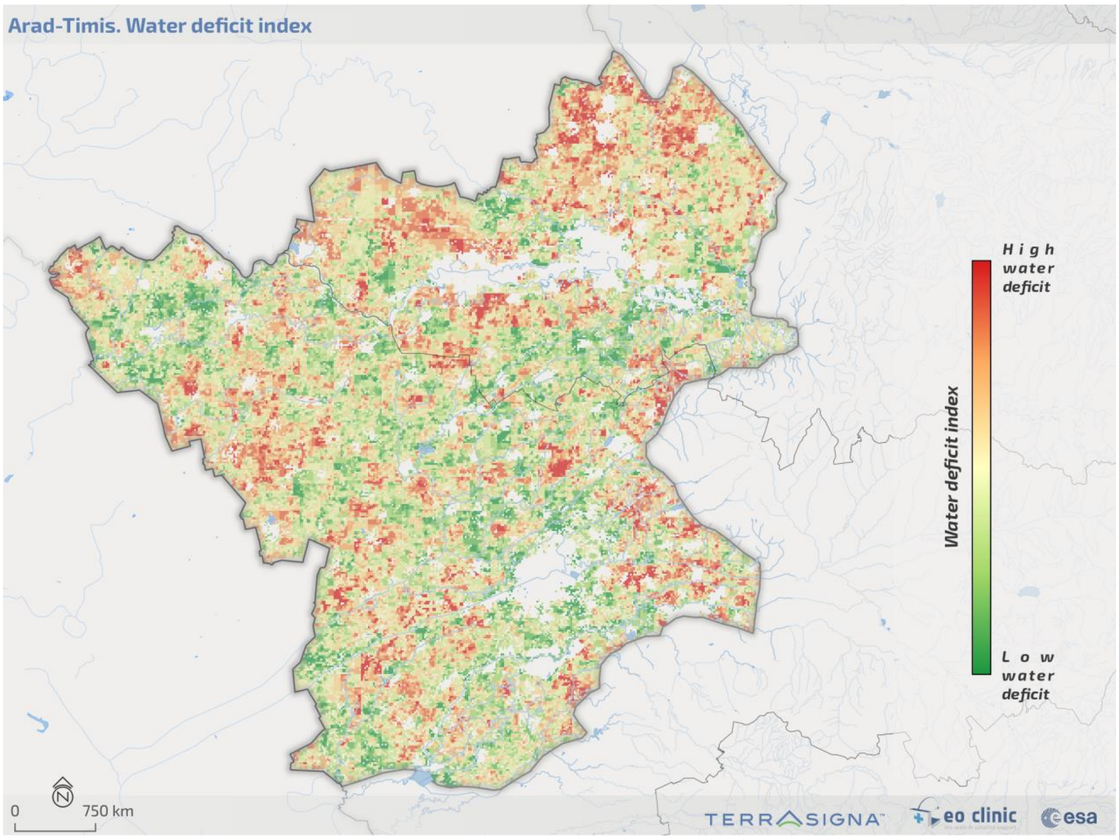


FIGURE 43: Arad-Timiş. Water Deficit Index

3.2.2.3.2 AOI3 – Arad-Timiş. Water Supply Potential

The Water Supply Potential Index was calculated based on four indicators (Fig. 44).

Slope, the first indicator considered in computing the Water Supply Index, shows a uniformity given by the low values, especially in the western part of the area, while in the eastern extremity, at the contact with Lipova Hills, there are areas of medium favorability.

The Vertical Distance Index filters the values even more, indicating the Vinga Plain as an area less suitable for irrigation purpose, mainly dues to its higher altitudes.

Proximity to Water Sources Index indicates least favorable areas within the Jimbolia Plain and the Timiş Plain, in the southwestern part of the area, as well as in Nădlac area, known for the frequent drought phenomena. In the rest of the AOI, the valleys of Mures, Bega and Timiş and their tributaries provide the water supply for irrigation and most agricultural areas are located inside a 5 km buffer from freshwater sources.

The layout of the irrigation facilities presents an inequality at the Arad-Timiş AOI level, as most of the already existing irrigation canals are located in the Lower Timiş Plain, in the south of the AOI, in Aranca Plain (west of the AOI) and in Arad Plain. Naturally, Vinga Plain, the highest subunit in the area, does not benefit from already existing irrigation systems, as this would not have been economically viable.

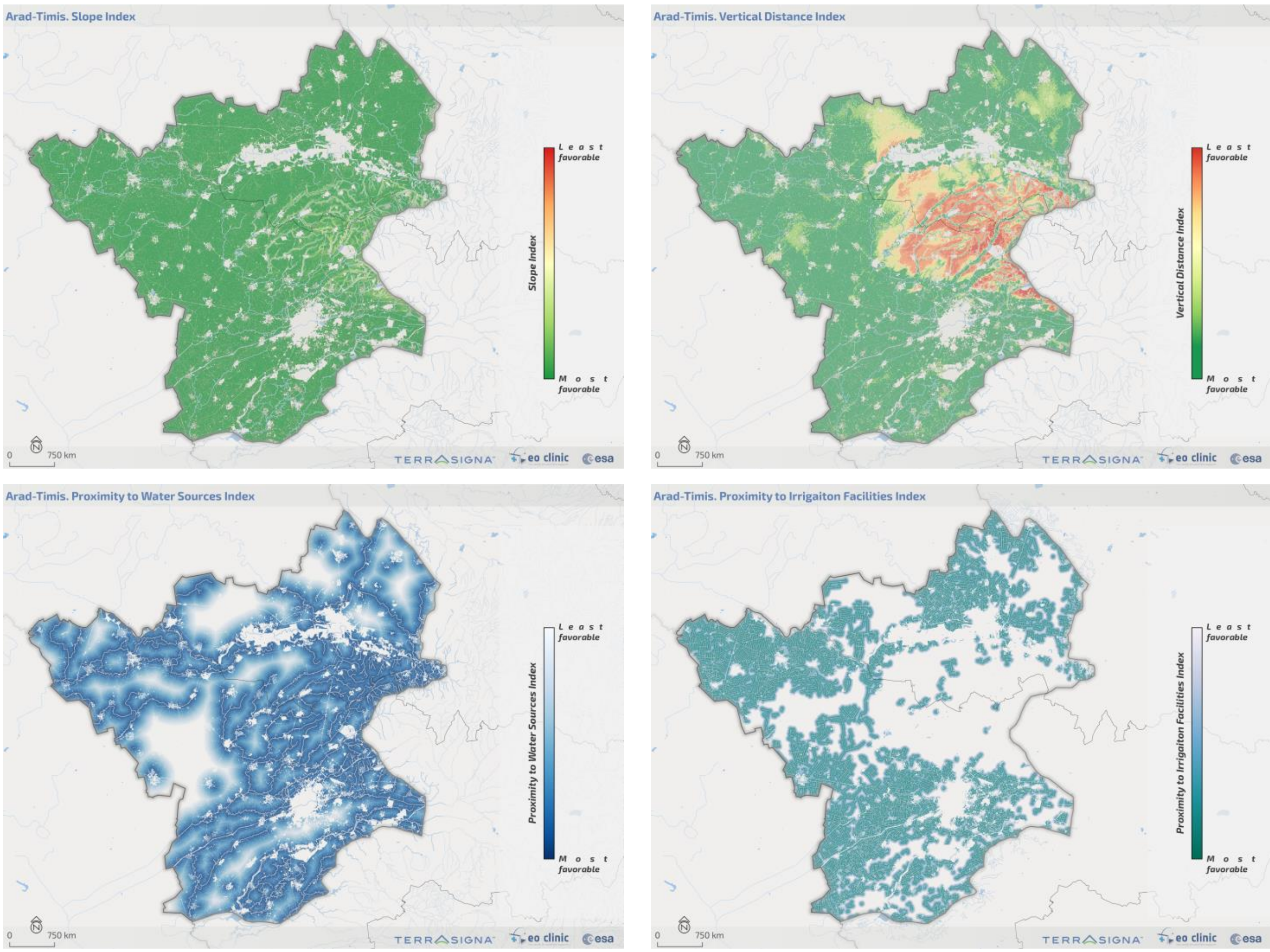


FIGURE 44: Arad-Timiş. Water Supply Potential Indicators

The Water Supply Potential Index (Fig. 45), calculated based on the 4 indicators, shows clear patterns. Vinga Plain, in the central eastern area of the AOI, has the lowest water supply potential, being geomorphologically different from the rest of the relief subunits. Moreover, areas with low water supply potential are found in the Nădlac Plain, Jimbolia Plain and, partially, Arad Plain. The areas with the highest water supply potential are those located along the main valleys and especially in the southern part of the Timiş Plain, known for the already existing irrigation systems.

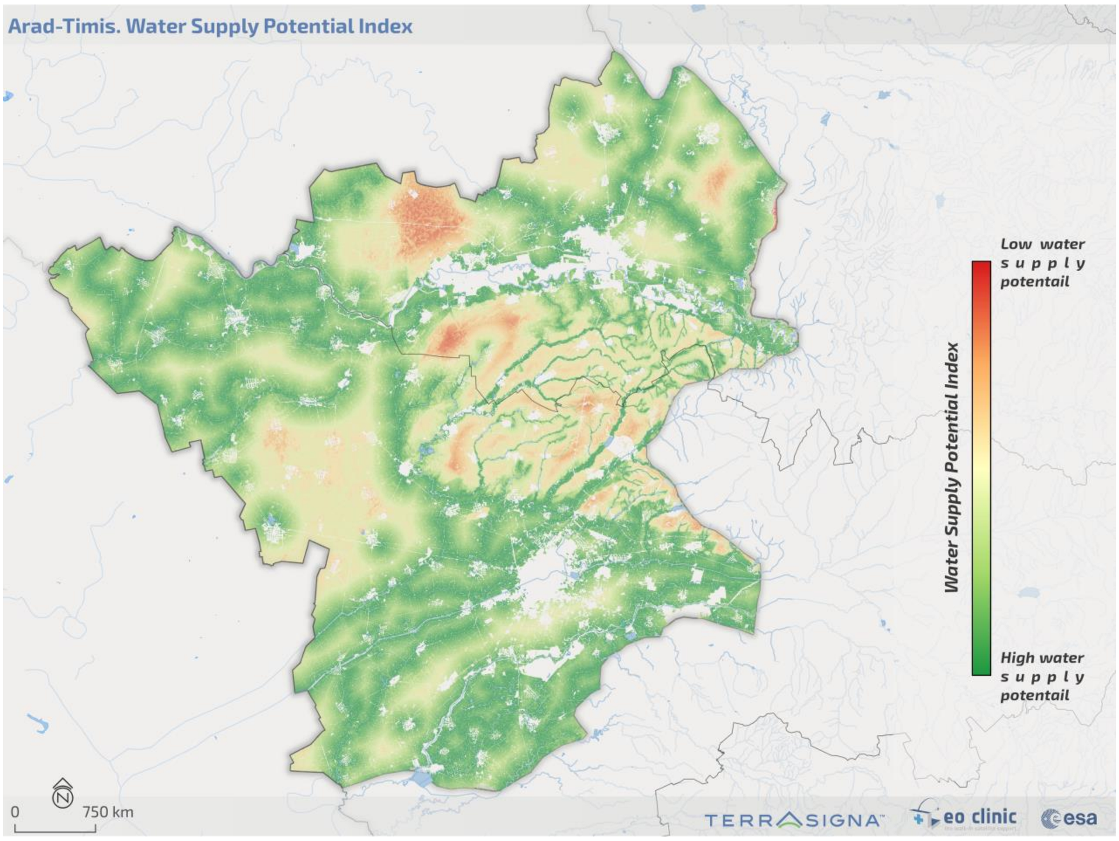


FIGURE 45: Arad-Timiş. Water Supply Potential Final Index

3.2.2.3.3 AOI3 – Arad-Timiş. Soil Irrigation Suitability

The fertile soils of the Western Plain mainly have medium-high values in terms of soil irrigation suitability (Fig. 46). The highest suitability is noticeable in the Arad Plain, as well as along the Bega River Valley, on the drained lands or in the south of the Mures Floodplain. The less favorable areas, most of them being excessively drained, are those in the southern part of Timiş Plain. Other agricultural limitations are represented by the Phreatic phase (shallow water table) and the presence of Sodic (Na / T> 6% within 100 cm) and Saline (electric conductivity> 4 mS.cm-1 within 100 cm) horizons, which contribute to the reduced irrigation suitability.

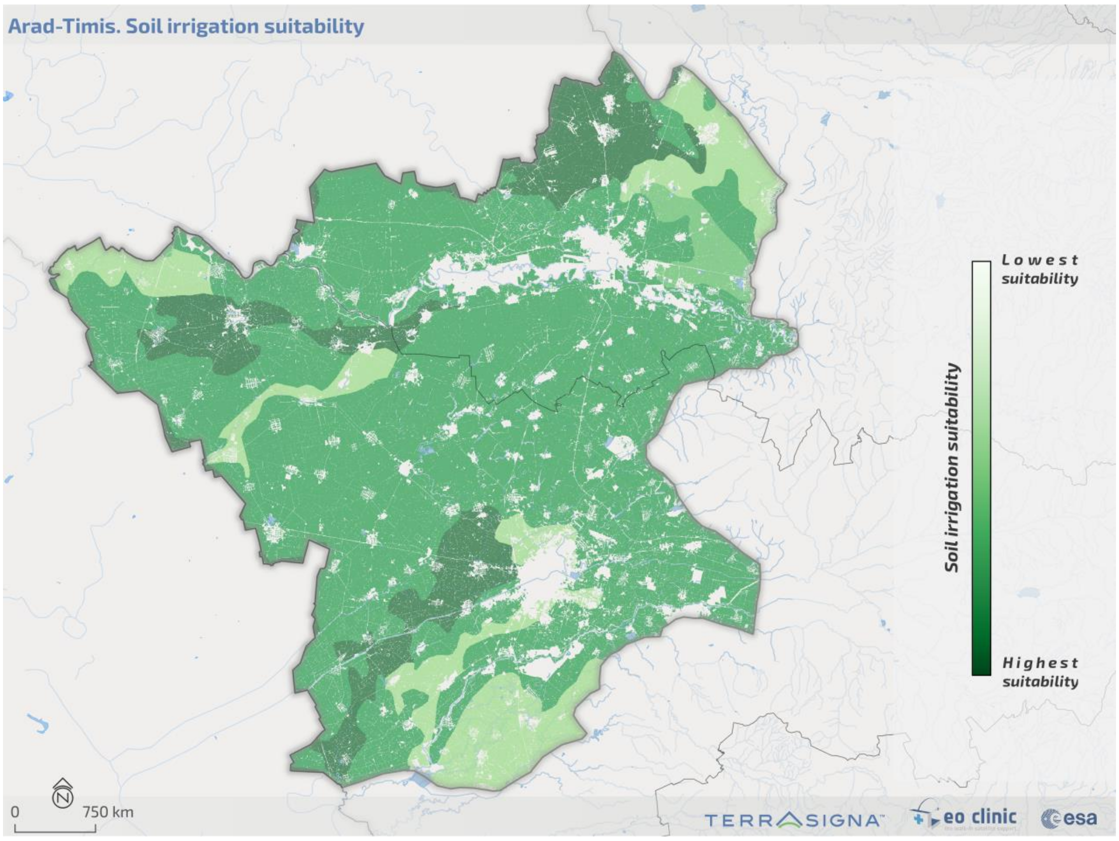


FIGURE 46: Arad-Timiş. Soil irrigation suitability

3.2.3 Quality Control and Validation

All the products have undergone systematic quality control, including all pre- and post-processing activities, which were subject to QC and QA checks.

4 EVALUATION OF FOLLOW-UP ACTIVITIES

This chapter evaluates the data and methodologies used for the current pilot and describes any problems or deficiencies that should be taken into account for a potential service roll-out.

4.1 Mapping of Irrigated Areas

In terms of follow-up activities for the Mapping of Irrigated Areas task, the listed activities can be considered:

- Detailed analysis and mapping of irrigated areas, based on multiple optical very high resolution data. For the current purpose of the study, the Sentinel-2 10-m spatial resolution is considered to be adequate. Moreover, the spectral resolution (the large number of spectral bands available) represents an important advantage in analyzing agricultural area over satellite images of better spatial resolution, but poorer in terms of spectral information. Moreover, the Copernicus free and open data policy, together with the long-term availability certainty, are important factors that highly help the developed solutions enter the European market and trigger collaborations between government agencies (regional or national Paying Agencies) and private-sector companies.
- Usage of additional data, such as field data, that can be collected during onsite visits.
- A large temporal dimension for the irrigation potential assessment would also be interesting for the study, in order to identify the changes over the past 30 years and the relationship to the decline of the irrigation facilities, to identify the areas most prone to drought and assess the vulnerability trends in relationship to the seasonal behavior and also to the rainfall variability.
- A future extension and scaling of the service might also benefit from the high-spatial resolution (10 m) pan-European High-Resolution Vegetation Phenology and Productivity products (HR-VPP), based on Sentinel-2 data, expected to become available in May 2021.
- Integration of agricultural productivity data and its dynamics would be extremely useful in understanding the drought impact versus irrigation advantages over different cropping patterns;
- Correlation / validation with the existing information in the official statistics provided by INSSE and at the level of the County Agricultural Directorates.
- Establishing correlations between crop type maps and agronomic information on plant water needs and plant grouping according to this need. An example is given in the table below (Table 23).

TABLE 23: Example of crop grouping according to water demands (FAO, 1979)

Group	Examples	Irrigation characteristics
I – plants with low water demand	Straw cereals, legumes, etc.	The interval between two waterings is about 33 days.
II – plants with medium water demand	Corn, sugar beet, sunflower, potatoes, perennial herbs - first year etc.	The interval between two waterings is about 25 days.
III – plants with high water demand	Beet for fodder, fodder maize, perennial herbs – second year etc.	The interval between two waterings is about 20 days.

Regarding possible future developments of the methodologies used:

- Taking into account the specificities of the agricultural landscape in Romania and especially the land fragmentation trends, the small narrow plots are not suitable for SAR analysis for crop type identification, taking into account the noise level, despite the good spatial resolution of Sentinel-1 images. Moreover, as stated before, in terms of Overall Accuracy (OA), the classification result using only Sentinel-2 imagery reached 0.98. Thus, a major increase in Overall Accuracy using SAR data was not foreseen.

  However, SAR data could be used for a better quantification of soil water content and mapping of irrigated areas. Testing of soil moisture retrieval methodologies, based on SAR data is also recommended.

- For possible further developments, it is necessary to introduce filters that emancipate descriptors in relation to the type of crop, as well as calibrations that allow the use of all descriptors together, for a synthesis conclusion.

- Integrating information regarding the LPIS/plot plan and the crop type/crop class can open the possibility of refining and correcting the results at a higher level of quality and precision.

Other datasets that are considered to add value to further developments are listed under Table 24.

TABLE 24: Mapping of Irrigated Areas. Datasets useful in follow-up activities

Dataset	Justification / Importance of integration in the analysis	Authorized Institution / Institution that Manages the Dataset
Yearly datasets regarding exact parcel locations **(and farmers' declarations regarding crop types)**	The dataset is essential for the computation of crop type maps for different agricultural seasons.	APIA (Agenţia de Plăţi şi Intervenţie pentru Agricultură - Agency for Payments and Intervention in Agriculture) / MADR (Ministerul Agriculturii şi Dezvoltării Rurale - Ministry of Agriculture and Rural Development)
Annual on-site compliance verifications of the farmers that applied for subsidies	The dataset would be extremely useful in validation activities (validating the computed crop type maps).	APIA (Agenţia de Plăţi şi Intervenţie pentru Agricultură - Agency for Payments and Intervention in Agriculture) / MADR (Ministerul Agriculturii şi Dezvoltării Rurale - Ministry of Agriculture and Rural Development)
Physical blocks in which at least one farmer uses irrigation (extracted from LPIS)	The dataset would be extremely useful in validation activities (validating the irrigated areas classification). The dataset has also been used by the Ministry of Agriculture and Rural Development in analyzing areas facing significant natural constraints.	APIA (Agenţia de Plăţi şi Intervenţie pentru Agricultură - Agency for Payments and Intervention in Agriculture) / MADR (Ministerul Agriculturii şi Dezvoltării Rurale - Ministry of Agriculture and Rural Development)

4.2 Quantifying Irrigation Suitability

In terms of follow-up activities for the Quantification of Irrigation Suitability task and a possible scaling up of the service at national level, the listed activities can be considered:

- Detailed analysis of the identified hotspots, based on higher resolution EO data.
- Integration of agricultural productivity data and its dynamics, as well as information on the irrigation efficiency of different agricultural crops (harvest without irrigation / harvest with irrigation - t / ha) would be extremely useful in understanding the drought impact versus irrigation advantages over different cropping patterns.
- Integration of information on agricultural productivity and quantifying it through different indicators calculated on the basis of EOs or data sets - e.g .:
    - Productivity Trajectory (related to rate of change of productivity over time);
    - Productivity Performance (a measure of how productivity in an area compares to that of similar areas);
    - Productivity State (compares current productivity in an area to past productivity in the same area);
    - UNCCD - Land Productivity Dynamics (LPD) dataset and any updates to it.
- Integration of agronomic information in order to choose a proper irrigation method, in accordance with current international standards and FAO recommendations[1].
- Validation based on information on ANC (areas with natural constraints) attributes, delivered in geospatial format, not only in tabular format and at administrative unit level.
- Validation activities based on LUCAS data sets: Land Use and Coverage Area frame Survey vector (points) - 2x2 km^2 grid, 2018 and field photos provided.

Regarding possible future developments of the methodologies used:

- **Water Deficit**: Extension of the analysis period is required, in order to cover at least 20 years (compared to the 5 years addressed in this pilot study). A possible development of the service could involve the integration of additional datasets, provided through the Copernicus Global Land Monitoring Service (Table 25).

TABLE 25: Water Deficit. Additional datasets useful in follow-up activities

Dataset	Type (vector/raster)	Spatial resolution	Temporal resolution / Update frequency
Surface Soil Moisture	raster	1 km	daily or 10 days mean
Vegetation Condition Index	raster	1 km	10 days
Vegetation Productivity Index (2013 - 2018)	raster	1 km	10 days

- **Water Supply Potential**:
    - Under the pilot framework, all freshwater sources vector data sets that could be downloaded from the ANCPI geoportal were used. However, in order to get as close as possible to reality, it is necessary to filter the data sets introduced in the analysis as freshwater sources according to their specificity and potential for irrigation (e.g. river flows, chemical concentration limitations, turbidity, etc.). Moreover, this filtering should also be performed using a possi-

[1] http://www.fao.org/3/s8684e/s8684e08.htm

ble legal basis regarding the rules for extracting volumes of water from surface sources. From our knowledge, at present, in Romania there is no such legislative framework.
  - Important updates of the computed indexes could be based on a clear delineation between working/functional and disaffected existing irrigation infrastructure.

- **Soil Irrigation Suitability**: Under the pilot framework, lower resolution freely available datasets were used to quantify soil irrigation suitability - the European Soil Database v2.0 (1: 1,000,000 scale), provided by JRC / ESDAC (European Soil Data Center). Using a higher resolution data set (eg: Digital soil map of Romania - SIGSTAR 200, based on the Soil Map of Romania at a scale of 1: 200,000) would allow the inclusion of additional limitations and restrictions, thus providing a more accurate image of ground truth, on a much more appropriate scale. The extra information that can be included refers to:
  - Limitations due to soil salinity – salinization / alkalinisation;
  - Limitations due to other soil chemical properties – e.g. acidity;
  - Limitations due to some soil physical characteristics – e.g.: rough texture and wind erosion, fine texture, low carrying capacity, low edafic volume;
  - Limitations due to land coverage (e.g.: presence of rocks, stones) or non-uniformity;
  - Limitations due to humidity excess – e.g.: freatic humidity excess, stagnant humidity excess, outflow flooding;
  - Limitations due to erosion or sliding – e.g. land slope, erosion risk and surface erosion; depth erosion, sliding or collapse.

Other datasets that are considered to add value to further developments are listed in Table 26.

TABLE 26: Quantification of Irrigation Suitability. Datasets useful in follow-up activities

Dataset	Justification / Importance of integration in the analysis	Authorized Institution / Institution that Manages the Dataset
Existing irrigation systems – \`Hydrology - Surface water\` layer (Water Cadastre in Romania)	The dataset is important in computing an indicator regarding the proximity of irrigation facilities, in order to assess the viability of irrigation solutions. What is more, an important information is represented by the exact location of existing irrigation infrastructure, with a clear delineation between working/functional infrastructure and disaffected one - data owner: ANIF (if the data exists and can be provided in a geospatial format).	ANAR (Administraţia Naţională Apele Române - National Administration "Romanian Waters") / ANIF (Agenţia Naţională de Îmbunătăţiri Funciare - National Agency for Land Improvements)
Freshwater resources \`Hydrology - Surface water\` layer (Water Cadastre in Romania)	The dataset is important in computing an indicator regarding the proximity of freshwater resources, in order to assess the viability of irrigation solutions.	ANAR (Administraţia Naţională Apele Române - National Administration "Romanian Waters")
Water management infrastructure (e.g. water pumping stations, reservoirs, water catchments etc.)	The dataset is important in computing an indicator regarding the proximity of irrigation facilities, in order to assess the viability of irrigation solutions.	World Bank (Past projects of WBG, e.g. - Investment Guide for Water and Wastewater Projects, 2015 - *http://documents1.worldbank.org/curated/en/537831467992819404/pdf/Investment-guide-for-water-and-wastewater-projects.pdf*, Romania Water Diagnostic Report, 2018)

Dataset	Justification / Importance of integration in the analysis	Authorized Institution / Institution that Manages the Dataset
Digital soil map of Romania (SIGSTAR 200) based on the Soil Map of Romania at a scale of 1: 200,000, National Research-Development Institute for Pedology, Agrochemistry and Environmental Protection - ICPA	Data on soil characteristics (e.g. soil type, soil texture) are important in defining the soil ability to drain water, retain moisture and, implicitly, in determining the need for irrigation. The dataset has also been used by the Ministry of Agriculture and Rural Development in determining areas facing significant natural constraints.	ICPA (Institutul Naţional de Cercetare-Dezvoltare pentru Pedologie, Agrochimie şi Protecţia Mediului - National Research-Development Institute for Pedology, Agrochemistry and Environmental Protection) / MADR (Ministerul Agriculturii și Dezvoltării Rurale - Ministry of Agriculture and Rural Development)

Estimates of workload and related costs for products delivered in the context of this pilot are expressed in the initially submitted Financial Proposal and can be used as a reference for a possible scaling of the service.

TERRASIGNA is ready to share and discuss with the World Bank Group and national authorities more results / details from past trials in order to gain feedback and tailor the developed solutions on real needs and also provide estimates of the level of effort and the costs for future extentions of the service, demonstrating its scalability and transferability to other regions in Europe and the world.

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