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GEOINFORMATION MAPPING OF MOISTURE CONDITIONS IN SUMY REGION IN 2024 BASED ON THE COMBINED DROUGHT INDICATOR (CDI)

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The study presents the main results of geo-information mapping of the moisture conditions in the Sumy region in 2024 based on the Combined Drought Indicator (CDI). The analysis assesses the spatial distribution of drought phenomena, considering precipitation deficit, soil moisture, and vegetation response. Data from the European Drought Observatory and GIS analysis methods were used. The results identify areas at the highest drought risk and reveal moisture condition trends. The findings can be applied to improve water resource management strategies and climate adaptation measures.
Keywords: geoinformation mapping, CDI, drought, soil moisture, climate change, GIS analysis, Sumy region.

ГЕОІНФОРМАЦІЙНЕ КАРТОГРАФУВАННЯ УМОВ ЗВОЛОЖЕННЯ В СУМСЬКІЙ ОБЛАСТІ У 2024 РОЦІ НА ОСНОВІ КОМБІНОВАНОГО ІНДИКАТОРА ПОСУХИ CDI

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Подано результати геоінформаційне картографування умов зволоження в Сумській області у 2024 році, виконаного з використанням комбінованого індикатора посухи (CDI). Аналіз включає оцінку просторового розподілу посушливих явищ, враховуючи дефіцит опадів, вологість ґрунту та реакцію рослинності. Використано дані Європейської обсерваторії посух та методи ГІС-аналізу. Результати дозволяють визначити регіони з найбільшим ризиком посухи та оцінити тенденції змін зволоження. Отримані дані можуть бути використані для вдосконалення заходів управління водними ресурсами та адаптації до кліматичних змін.
Ключові слова: геоінформаційне картографування, CDI, посуха, зволоження ґрунту, кліматичні зміни, ГІС-аналіз, Сумська область.

Moisture conditions are an important indicator that gives a general idea of a certain area's meteorological and climatic system. In this paper, the Composite Drought Indicator (CDI) calculated by the European Drought Observatory (EDO) to monitor this phenomenon and the impact of droughts on agricultural vegetation and crops in Europe is used to assess the degree of moisture [3]. Drought is usually identified with a period characterized by unusually persistent dry weather conditions that affect the hydrological balance. The scientific literature distinguishes between at least three types of droughts [4]: meteorological drought, which corresponds to a defined period with a prolonged precipitation deficit; agricultural drought, a period characterized by severe soil moisture anomalies with a negative impact on vegetation and crops; and hydrological drought, when water shortages affect river flows, water levels in lakes and reservoirs, and groundwater levels.

Of the above, agricultural drought is characterized by a potential reduction in vegetation and crop yields due to meteorological and critical soil conditions. By integrating static crop masks, CDI provides valuable information to assess the impact of drought on cultivated areas during the growing season.

The CDI dataset is a collection of raster maps with a spatial resolution of about 5 km and WGS84 as the geographic coordinate system. The CDI maps are available from 2012 to the present and are regularly updated every 10 days, which is a reasonable frequency for crop stress monitoring, given that typically 10-20 days of water stress can seriously affect the final yield [5]. To calculate the CDI, the EDO integrates three complementary indicators that characterize moisture conditions: the standardized

precipitation index [7], the soil moisture index anomaly [6], and the anomaly of the fraction of absorbed photosynthetically active radiation [2].

The CDI assumes that drought develops as a sequential process, where a lack of precipitation (watch stage) causes deterioration of soil moisture conditions (warning stage), which in turn leads to negative impacts on vegetation, especially on arable land (alert stage). From a computational point of view, each pixel on the CDI map summarizes the simultaneous values of the three anomaly indicators (SPI, SMA and FAPAR) in 10 days and the CDI class assigned to this pixel in the previous 10-day period (T-1). It is worth noting that FAPAR is more sensitive to changes in plant water stress than NDVI, as it reflects photosynthetic efficiency and the ability of the vegetation cover to utilize available radiation. This makes it a reliable indicator of plant response to drought conditions, especially in conditions of prolonged moisture deficit. Whenever one or more of the three input indicators (SPI, SMA, FAPAR) fall below (exceed) the respective critical thresholds, CDI assigns the pixel to one of the three main drought stages mentioned above.

In this study, we used maps with CDI values for 12 months of 2024, calculated, as usual, for the 2nd decade of each month. The beginning of the year (January-February) was characterized by wet conditions (no drought), both in Sumy region and in the surrounding areas (Fig. 1a). Approximately the same conditions were observed in early spring. However, the results of observations in adjacent areas already indicated that drought was observed (Fig. 1b), and in some places even reached significant values in terms of precipitation deficit: SPI-1≤ -2 or SPI-3≤ -1 (warning level).

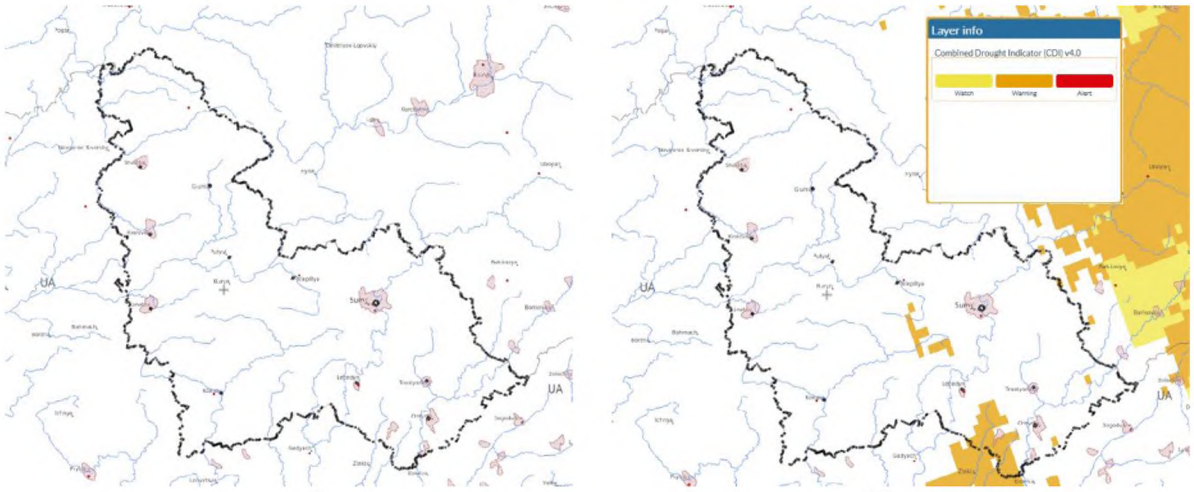
Late spring and early summer (May-June) are characterized by a rapid increase in aridity. While in May the drought covered only the eastern parts of the region, in June it spread throughout its territory, except for the river valleys of the Ret', Seim, Psel and Vorskla, as well as in some parts of the valleys of the Kleven', Sula (where the Tern River flows into it), Hrun' and some other rivers (Fig. 2b). July and August were characterized by pronounced dry conditions. Only the extreme northern part of the region (in Znobivka and Svyha river basins) was drought-free in the former Seredyna-Buda district (Fig. 3a).

In the rest of the territory, there was a pronounced precipitation deficit. In about 50% of the territory, the drought began to lead to negative anomalies in vegetation growth (FAPAR anomaly ≤ -1), which usually occur in combination with a precipitation deficit and negative soil moisture anomalies (alert level). In early autumn, drought covered the entire territory of the region, including the aforementioned northern areas, but the intensity of the drought has somewhat weakened (Fig. 3b).

While in September there was still a certain parity of areas where the «alert» and «warming» levels were observed, in October the alarm level occupied small areas, approximately the same as where the drought had ceased to be recorded (Fig. 4a). Late fall and early winter were characterized by further weakening of aridity. In November, the absence of drought began to be recorded in the northern part of the region and then spread to the northwestern part (Fig. 4b). Instead, the high level of aridity, which was still observed in November in some areas of the southern part of the region, was no longer recorded at all in December.

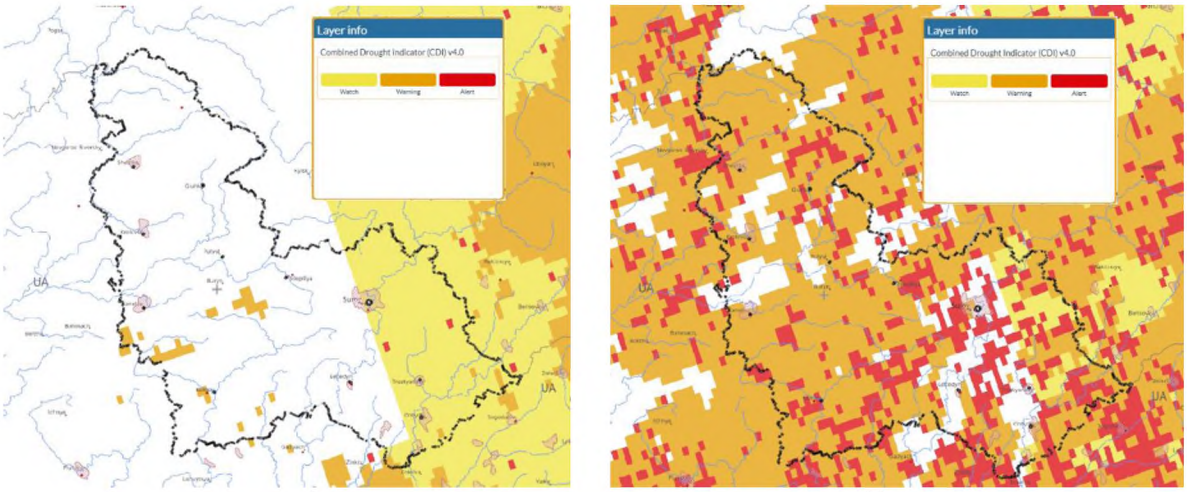
It is worth noting that CDI, by integrating meteorological and hydrological data and vegetation indicators, is a fairly reliable tool for drought assessment, especially about vegetation conditions, for example, when biomass reduction may be caused by factors other than water stress caused by drought. Identifying drought levels derived from an integrated approach can help in effective risk management and decision-making. Moreover, the use of spatial indicators of phenology (crop masks), which we plan to study in the future, provides an additional and more reliable assessment of the potential impact of drought on crops.

The «Compare indicators» tool opens up vast possibilities for assessing the aridity of the territory, which is a powerful analytical tool that significantly expands the ability of researchers to study spatial and temporal changes in arid conditions. It allows comparing up to 4 indicators, or up to 4 time series of the same indicator on different maps simultaneously. For example, it is possible to analyze how changes in SPI (soil water holding capacity) affect soil moisture retention and whether these changes reflect the response of vegetation recorded through FAPAR.



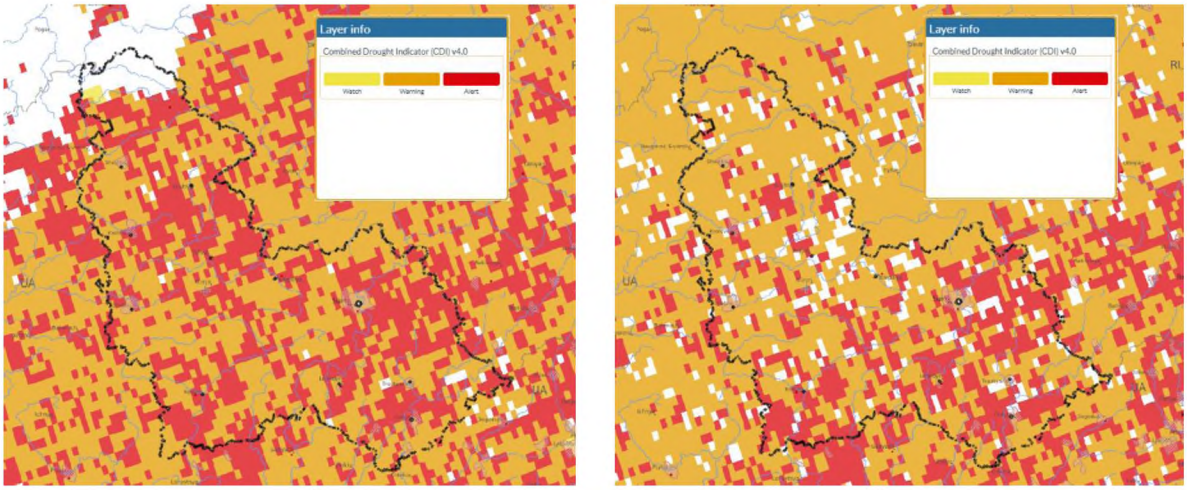
a) b)

Figure 1. Drought level according to CDI indicators: a) January, b) February



a) b)

Figure 2. Drought level according to CDI indicators: a) May, b) June

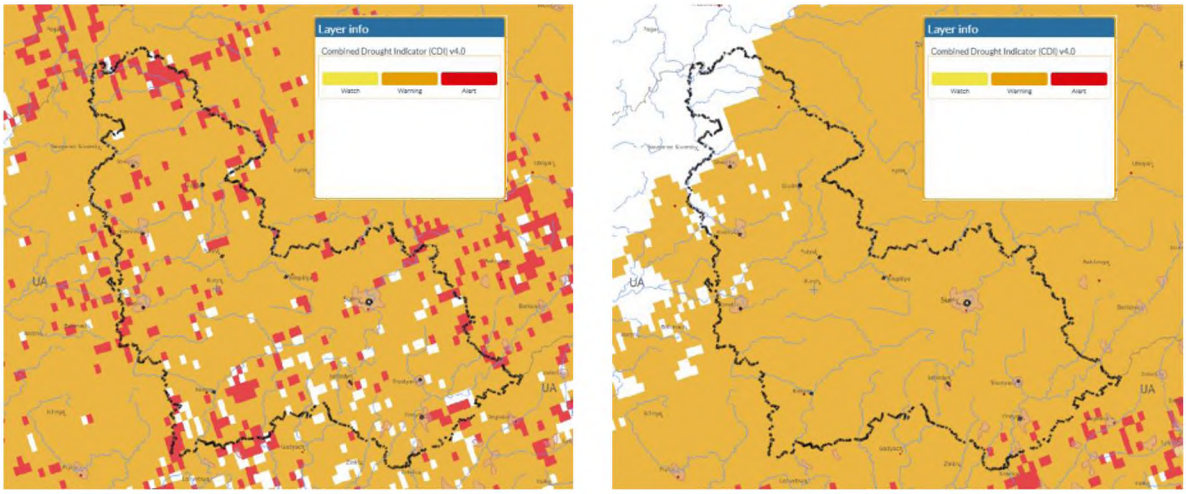


a) b)

Figure 3. Drought level according to CDI indicators: a) August, b) September

The capability to compare time series of the same indicator represents a valuable analytical tool, as it enables the assessment of both seasonal fluctuations and long-term trends in drought conditions.

This is particularly relevant for regions where droughts exhibit variability in intensity and duration across different years. Applying this function to the Sumy region allows for an in-depth investigation of historical changes in dry periods, offering insights into whether discernible trends indicate an increase in drought frequency or duration over past decades. Such an approach facilitates pattern recognition and enables the examination of correlations between different indicators, which is crucial for enhancing the accuracy of drought forecasting. Integrating multisource data within a single visual framework accelerates the identification of critical drought-prone areas and supports informed decision-making regarding drought mitigation strategies.



a) b)

Figure 4. Drought level according to CDI indicators: a) October, b) November

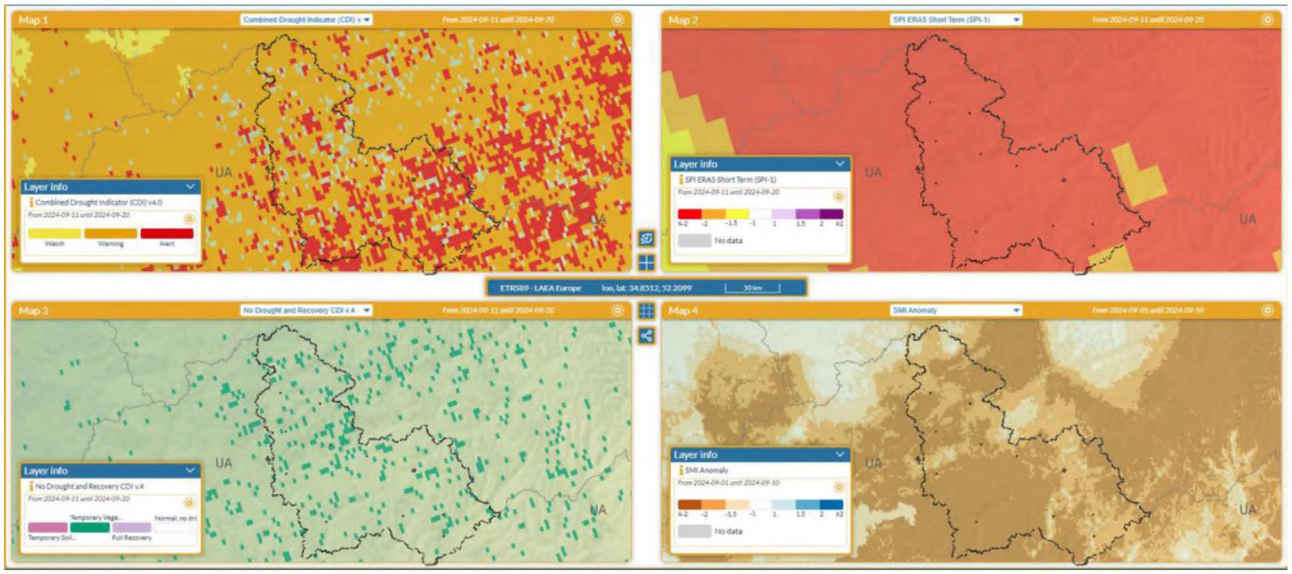


Figure 5. An example of a combined analysis of various indicators of moisture conditions in the Sumy region (September, 2024)

In this study, additional indicators were incorporated to refine further the assessment of moisture conditions and drought impacts: 1) ERA5 SPI, which provides spatial and temporal delineation of meteorological drought events. This index is calculated every ten days using the Standardized Precipitation Index (SPI) accumulated over one month (SPI-1) and is derived from the ERA5 reanalysis dataset, developed by the European Centre for Medium-Range Weather Forecasts (ECMWF); 2) Soil Moisture Index Anomaly (SMI Anomaly), which serves as a key metric for identifying the onset and

duration of agricultural drought conditions. Agricultural drought reduces soil moisture availability to a level that adversely affects crop yields. This indicator is computed within the EDO system every ten days using the proprietary LISFLOOD hydrological model [1]; 3) No Drought and Recovery Indicator, which functions as a complementary measure to the CDI and provides an inverse perspective, facilitating a more precise interpretation of moisture conditions within the region. This indicator is handy for distinguishing recovery phases and identifying areas transitioning from drought conditions to normal moisture levels (Fig. 5).

In this case, the CDI is an integrated indicator considering precipitation, soil moisture, and vegetation response, allowing for a comprehensive drought picture. The SPI ERA5 (SPI-1) complements this analysis by assessing precipitation anomalies at short intervals, which is important for detecting sudden and rapidly changing dry periods. SMA is justified as an indicator of soil moisture availability, as it allows us to assess how drought affects soil moisture, which is critical for agriculture and natural geosystems in the region. Of particular note is the inclusion of the No drought and recovery indicator, which helps to understand the recovery processes after drought and also allows us to identify regions that are no longer in a state of drought but may be vulnerable due to previous moisture deficits. This combination of indicators covers both short-term and long-term aspects of drought development, which is important for a comprehensive analysis of the situation in Sumy region.

Geo-information mapping of moisture conditions in the Sumy region in 2024 based on the Combined Drought Indicator (CDI) enabled the assessment of spatial and temporal patterns of water balance changes in the region. The analysis of the generated cartographic materials confirmed that drought phenomena exhibit spatial heterogeneity, with the most pronounced effects observed in the southern and central districts of the region. It was established that the key factors influencing moisture levels include precipitation deficits, declining soil moisture, and changes in vegetation cover, as confirmed by satellite monitoring data.

The findings highlight the necessity of considering regional moisture distribution patterns when developing water resource management strategies. The use of CDI in combination with GIS methods proves to be an effective tool for identifying areas at increased drought risk, which can support the adaptation of the agricultural sector to climate change. Further research should focus on improving moisture monitoring techniques by integrating local meteorological data and predictive models.

To summarize, the maps of the combined drought indicator, which has a daily update in the EDO, together with the use of weather forecast data, provide timely information on the modelled level of aridity of the meteorological situation and allow spatial coverage of the territory affected by drought or at risk of drought. In addition, time series analysis of CDI indicators can be used to assess the duration and severity of droughts.

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