

OCENA WPŁYWU WARUNKÓW METEOROLOGICZNYCH NA STAN ZDROWOTNY LASÓW W POLSCE, NA PODSTAWIE DANYCH Z REANALIZY ERA5 I WSKAŹNIKÓW SPEKTRALNYCH MODIS



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Czy i jaki jest wpływ zmian klimatu na kondycję lasów?



- Wskaźnik wegetacji – NDVI

MOD13Q1 i MYD13Q1 (MODIS na pokładzie satelitów Terra i Aqua)

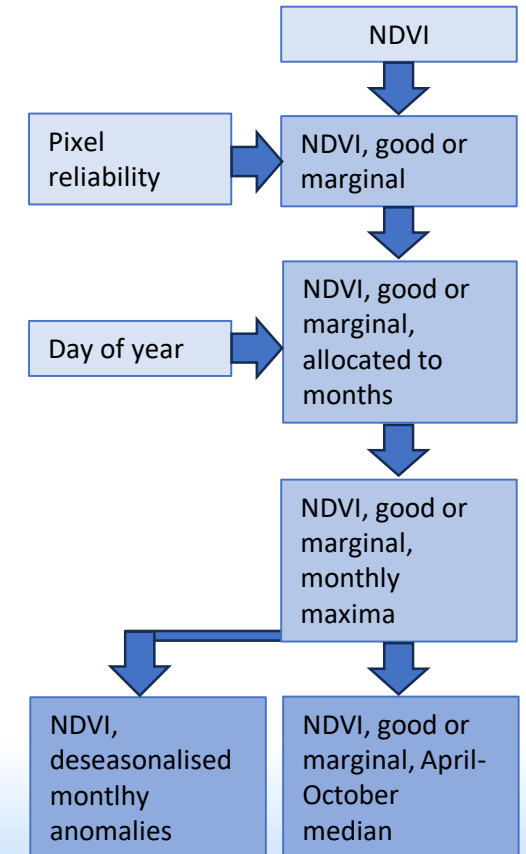
- Rozdzielczość przestrzenna: 250 m x 250 m
- Rozdzielczość czasowa: quasi 8-dniowa
 - Zagregowana do „growing season’s medians”
 - Zagregowana do „deseasonalised monthly anomalies”
- Zasięg przestrzenny: 48°N - 55°N i 14°E - 25°E
- Zakres czasowy: 2002-2022
- Warstwy:
 - NDVI
 - Pixel reliability
 - Day of year



- Dane meteorologiczne – T, P, ETo

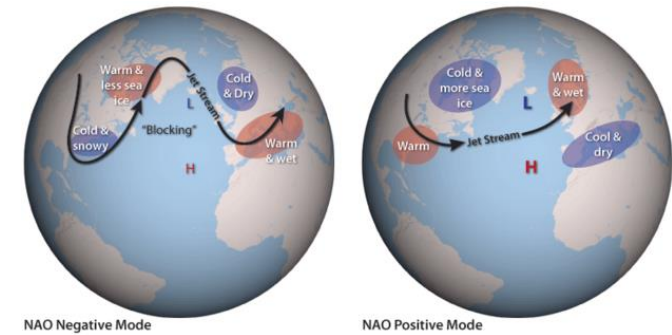
ERA5-Land

- Rozdzielczość przestrzenna: 0,1° x 0,1°
- Rozdzielczość czasowa: 1 h
- Zasięg przestrzenny: taki sam
- Zakres czasowy: 1971-2022
- Zmienne:
 - Temperatura T (°C)
 - Opady P (mm)
 - Ewapotranspiracja ETo (mm)



- Oscylacja Północnoatlantycka – indeks NAO

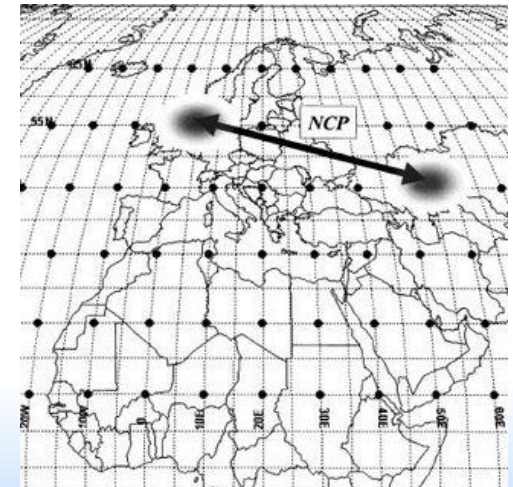
- Rozdzielczość czasowa: 1 miesiąc
- Zakres czasowy: 2002-2022
- Calculated on the basis of the Rotated Principal Component Analysis (RPCA), which is applied to monthly mean standardized 500 geopotential height anomalies in region 20°N to 90°N (and all longitudes) between January 1950 and December 2000. The anomalies are standardized by the 1950-2000 climatology



- North Sea Caspian – indeks NCP

obliczony na podstawie danych z ERA5-Land

- Rozdzielczość czasowa: 1 miesiąc
- Zakres czasowy: 2002-2022
- Calculated from the normalised 500 geopotential height difference between averages of North Sea (0°, 55°N and 10°E, 55°N) and northern Caspian Sea (50°E, 45°N and 60°E, 45°N) regions



Maski lasów

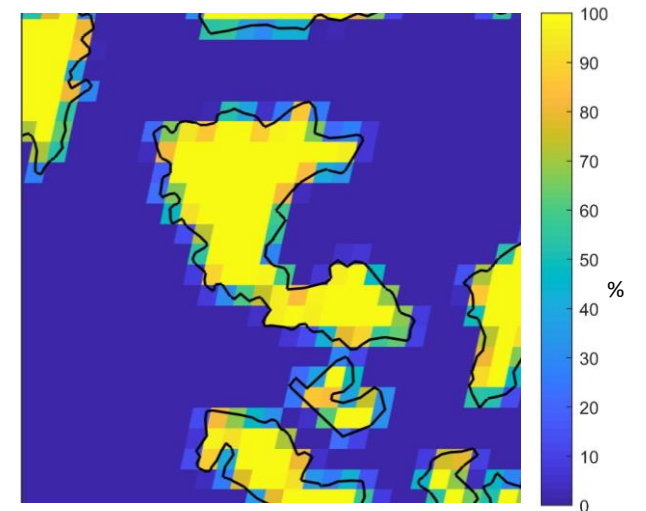
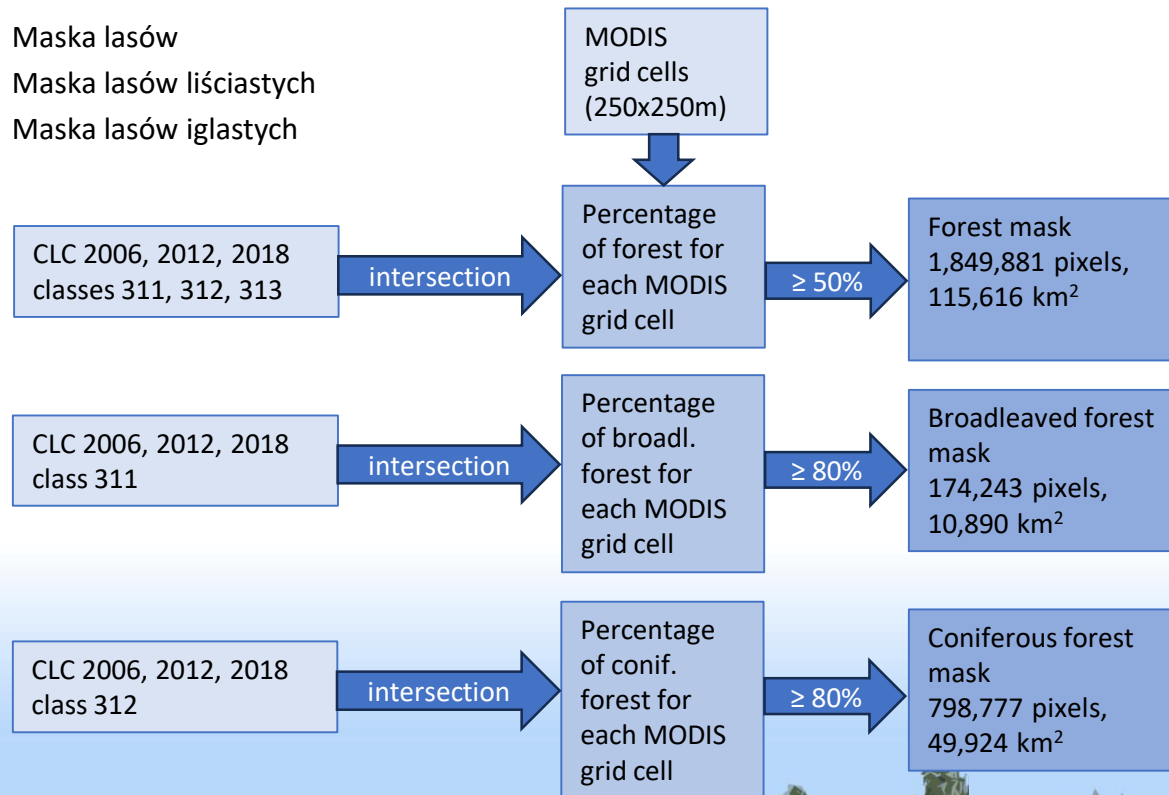
- Corine Land Cover (CLC) 2006, 2012 i 2018

- Klasy CLC:

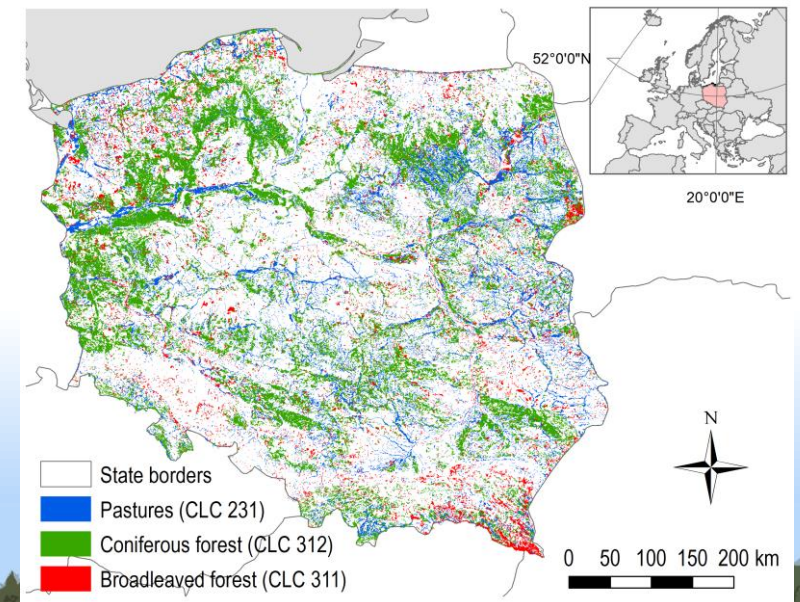
- Broadleaved forests (311)
- Coniferous forests (312)
- Mixed forests (313)

- Maski:

- Maska lasów
- Maska lasów liściastych
- Maska lasów iglastych

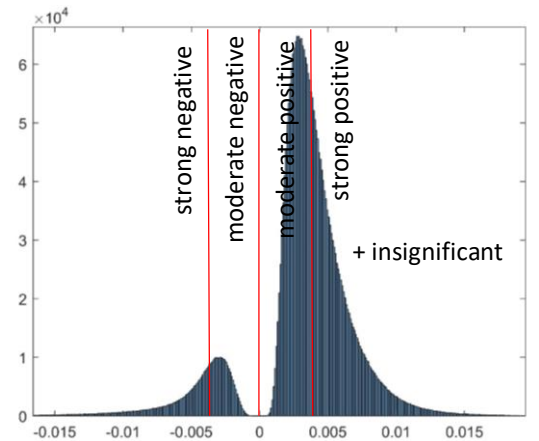


Percentage of forest in MODIS grid cells. Black lines depict CLC polygons

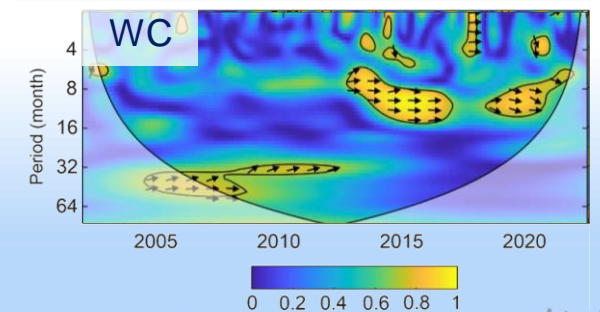
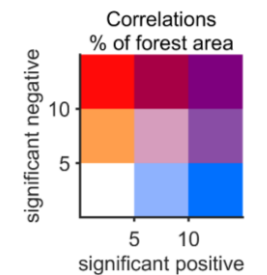


Spatial distribution of vegetation masks – broadleaved forest (CLC class 311), coniferous forest (CLC class 312)

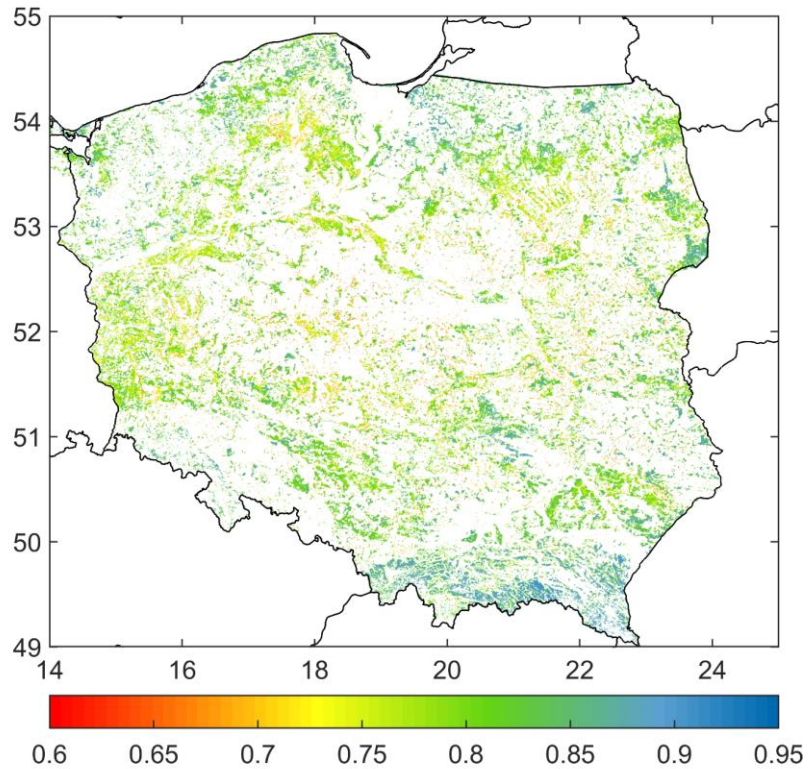
- Zmiany i zmienność NDVI i elementów meteorologicznych
 - Rozkład przestrzenny wartości średnich
 - Rozkład przestrzenny współczynnika kierunkowego trendu liniowego (podział na 5 klas)
 - Wieloletni przebieg wartości uśrednionych przestrzennie
- Związki NDVI z elementami meteorologicznymi
 - Kartogram złożony – w odniesieniu do nadleśnictw
- Analiza opóźnień w odpowiedzi NDVI na zmiany warunków meteorologicznych:
 - Analiza falkowa (Wavelet analysis)
 - Wavelet coherence (WC)
 - Współczynniki korelacji Pearsona z opóźnieniem (time lag)
 - Korelacje miesięcznych wartości NDVI z miesięcznymi wartościami elementów meteorologicznych z opóźnieniem od 0 do 36 miesięcy



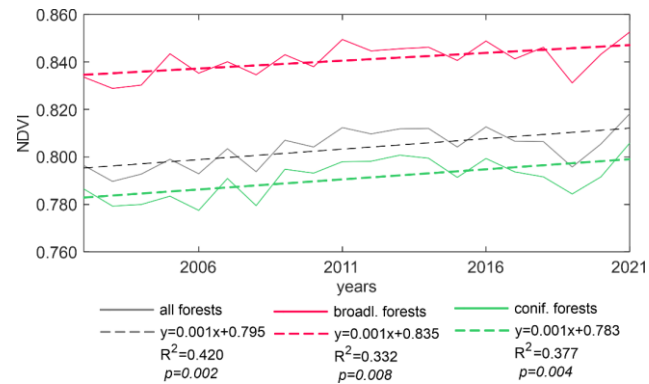
Histogram of slopes of statistically significant ($\alpha=0.05$) trends in changes in NDVI in forests in Poland in the period 2002-2021



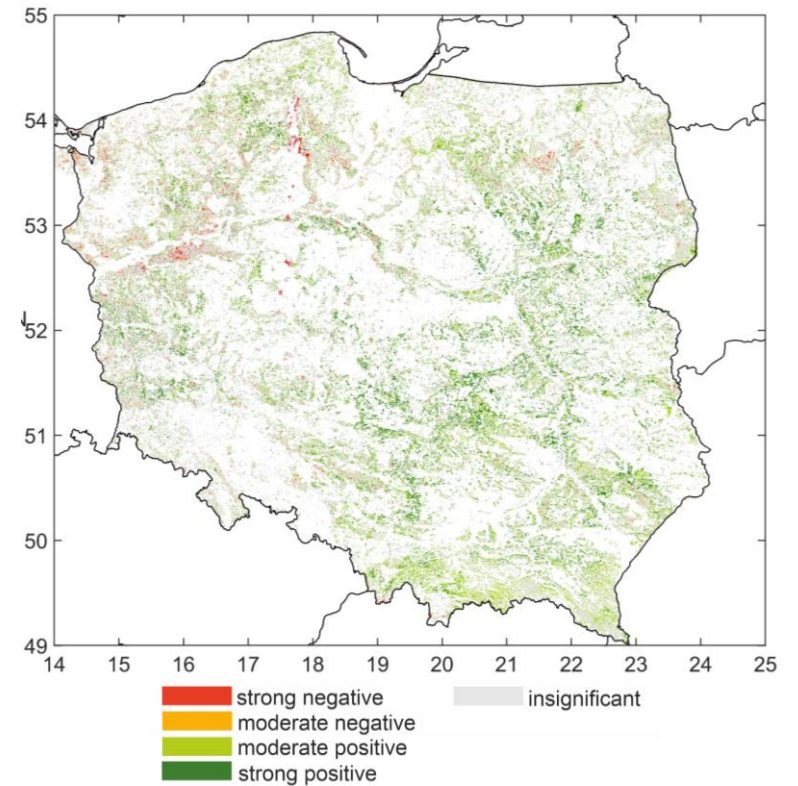
Zmienność NDVI w lasach w Polsce



Mean annual NDVI in Polish forests in the period 2002-2021

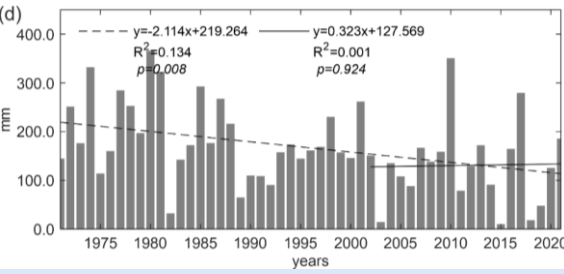
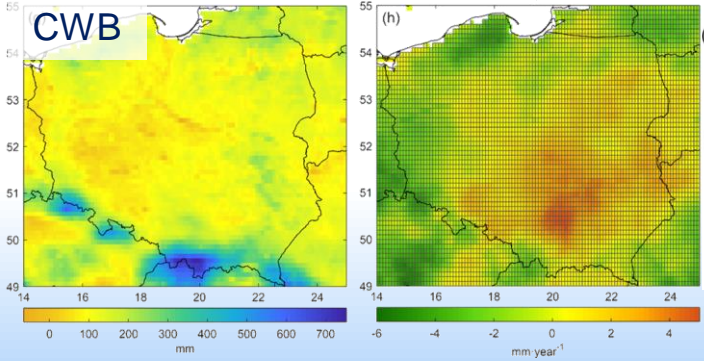
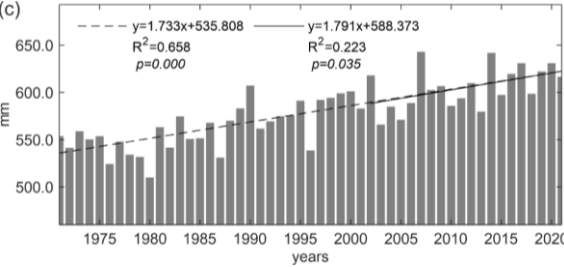
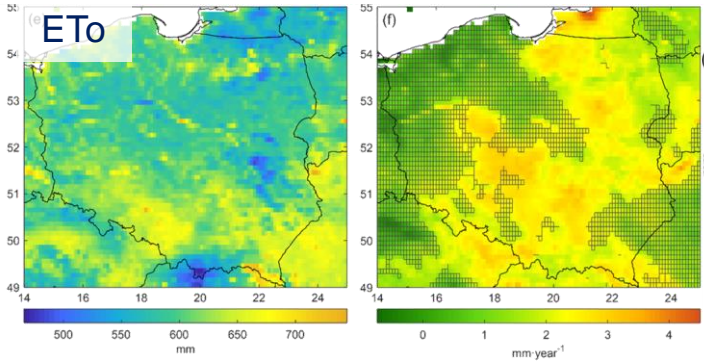
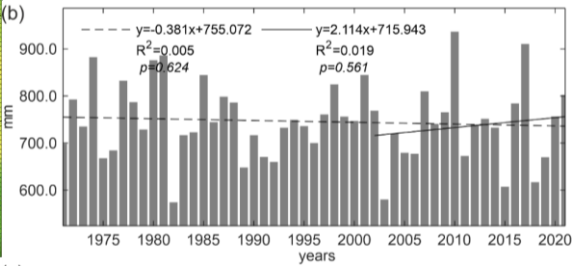
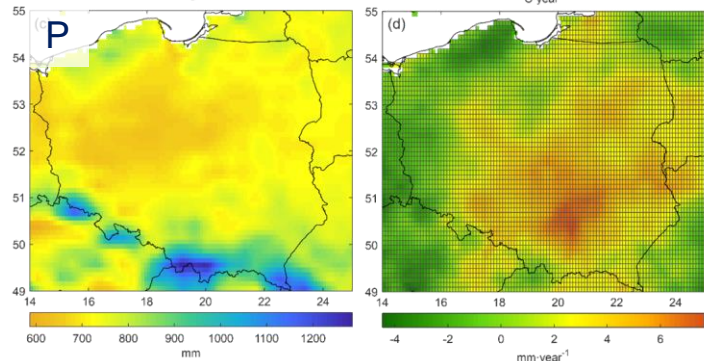
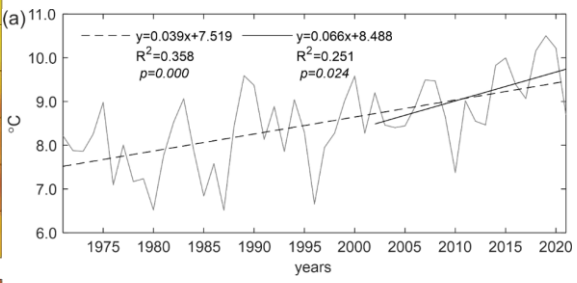
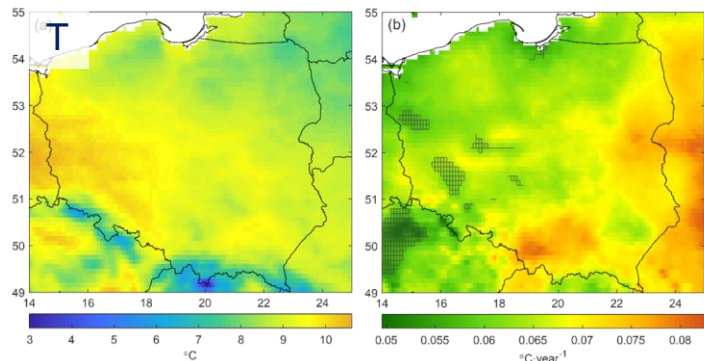


The course of mean annual NDVI in Polish forests in the period 2002-2021. The graph also shows the linear trends (dashed lines), the trend line equations, the coefficient of determination R^2 , and the statistical significance level p



Slopes of the trend in changes in mean annual NDVI ($\text{NDVI}\cdot\text{year}^{-1}$) in Polish forests in the period 2002-2021. The values of the trend's slopes are divided into 5 classes, according to their statistical significance at the significance level of $\alpha = 0.05$, and slope's steepness (1 insignificant and 4 significant classes)

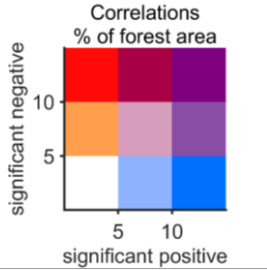
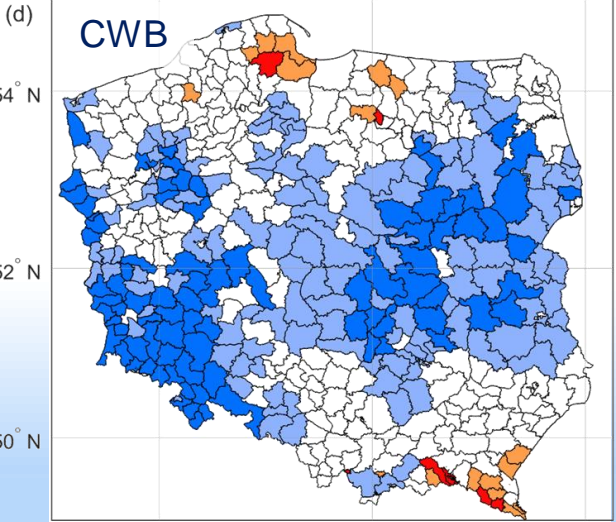
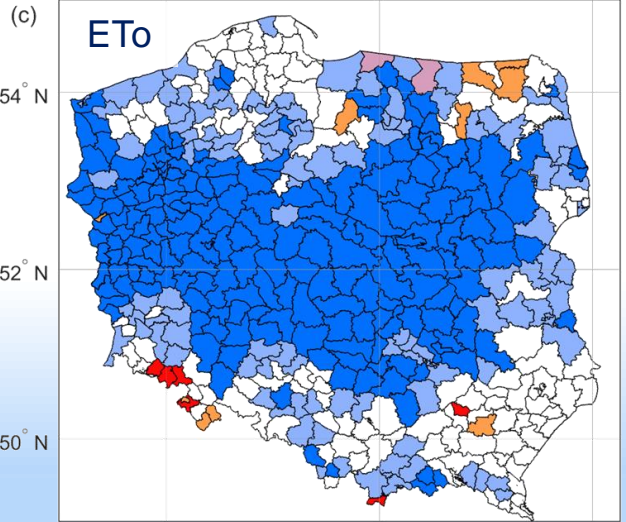
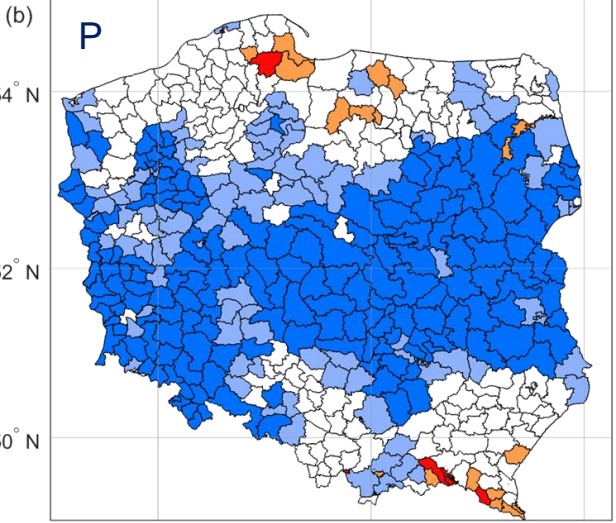
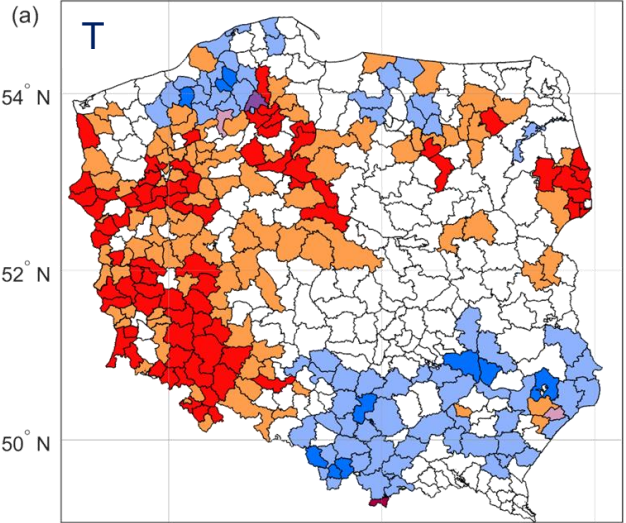
Zmienność elementów meteorologicznych



The course of mean annual T, and mean annual sums of P, ETo and CWB over Poland in the period 1971-2021. The graphs also show the linear trends in the period 1971-2021 (dashed lines), and the linear trends in the period 2002-2021 (solid lines), the trend line equations, the coefficient of determination R^2 , and the statistical significance level p

Mean annual T, P, ETo, CWB, and the slopes of the trend in changes in these elements over Poland during the period 2002-2021. The shading indicates the statistically insignificant slopes at the significance level of $\alpha = 0.05$

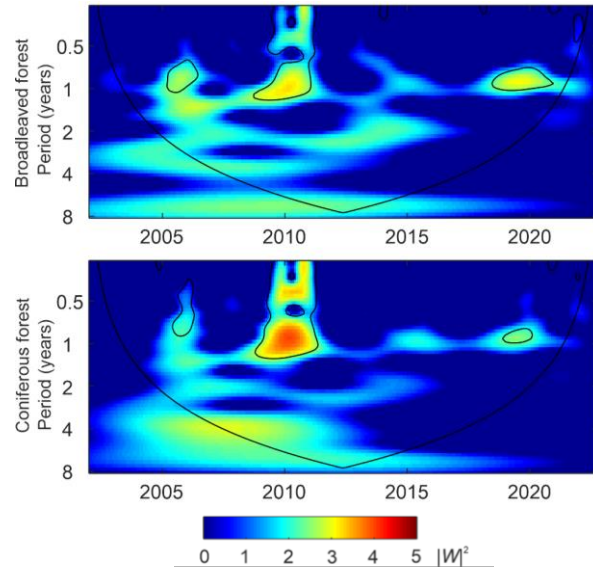
Korelacje NDVI z elementami meteorologicznymi – nadleśnictwa



Percentage of forest area covered with pixels with statistically significant ($\alpha = 0.05$) positive and negative correlations between NDVI and T, P, ETo, CWB in individual forest inspectorates in the period 2002-2021

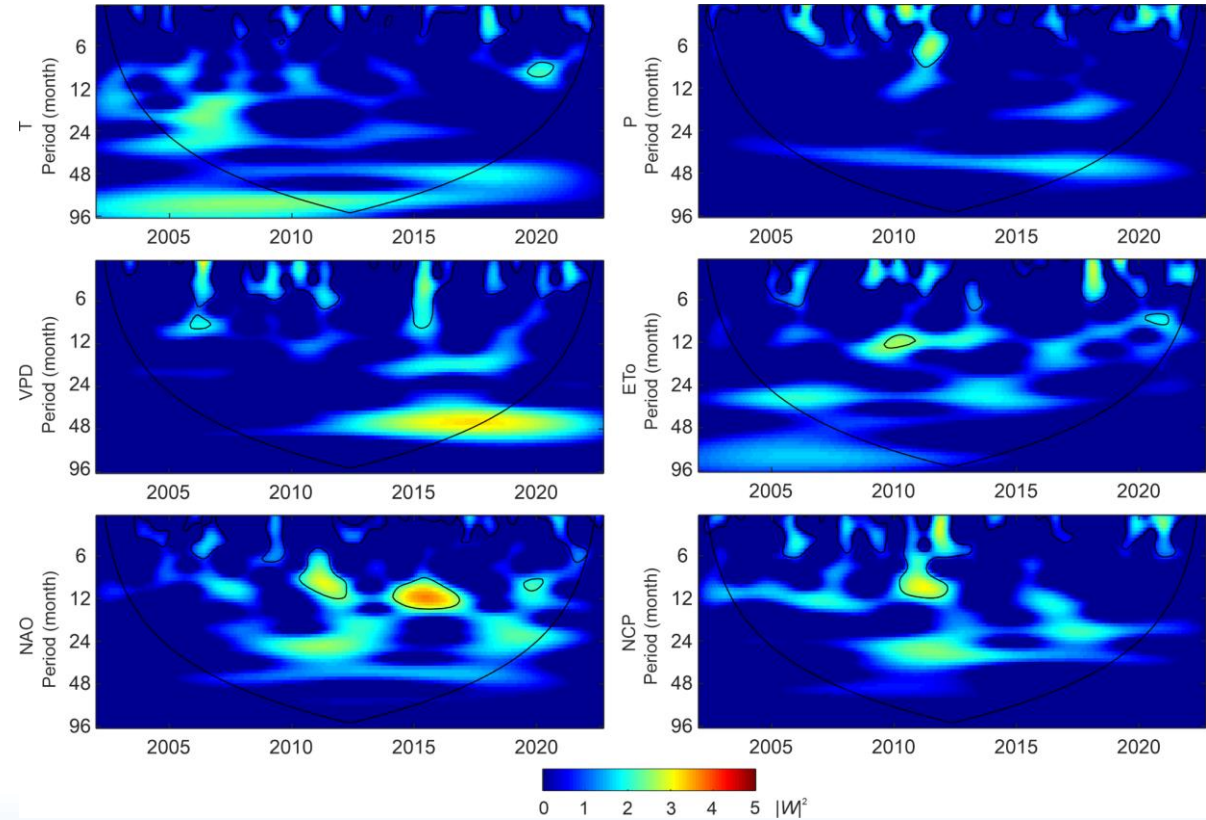
Analiza falkowa – NDVI oraz elementów meteorologicznych

NDVI



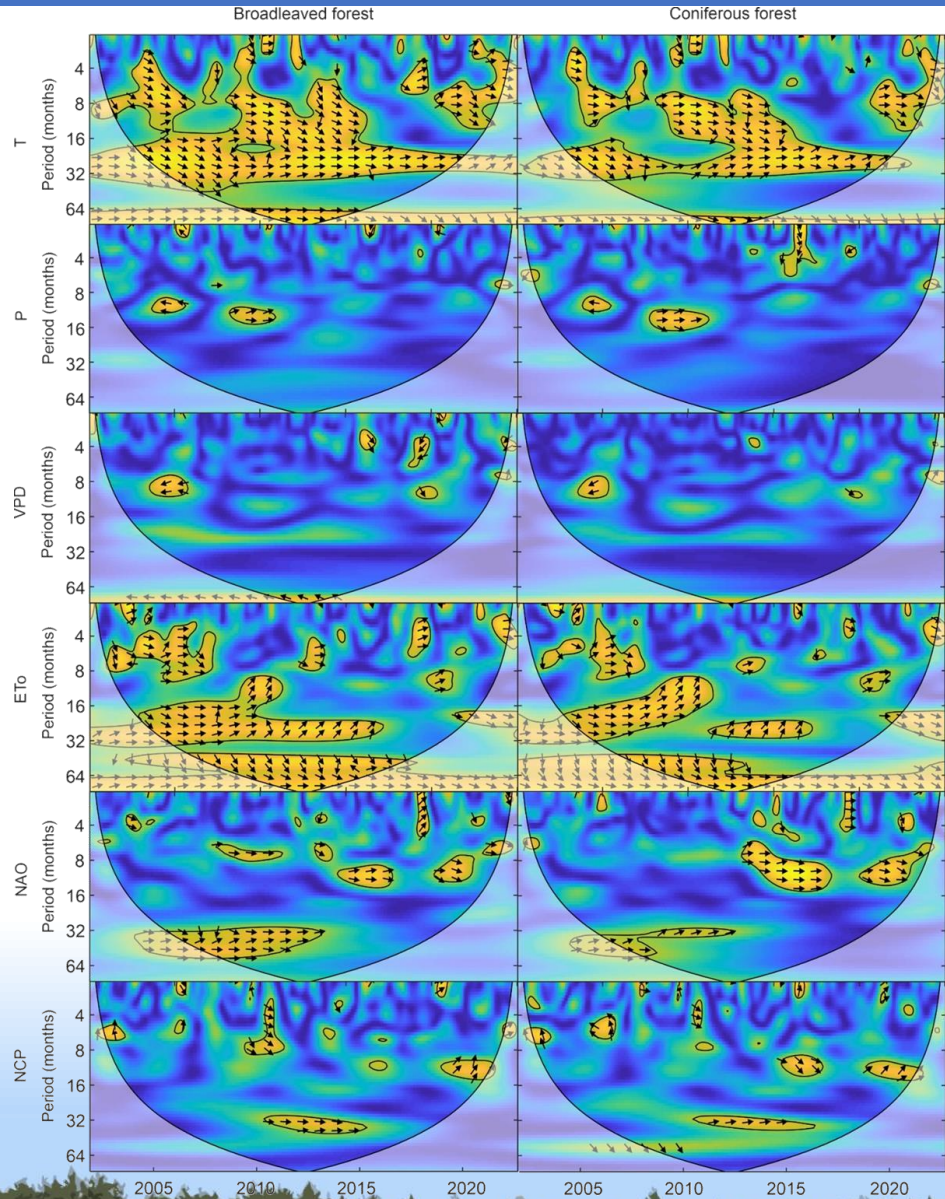
Wavelet power spectrum ($|W|^2$) for deseasonalised time series of NDVI for different forest masks during the period 2002-2022. The COI region is below the thick black line. Statistically significant areas at the level of $\alpha = 0.05$ are indicated by a thin black line

Elementy meteorologiczne i indeksy telekoneksyjne

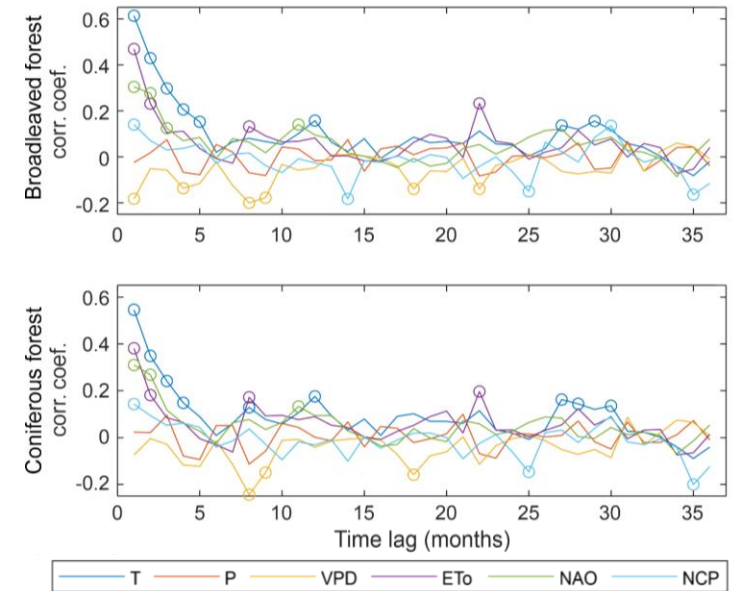


Wavelet power spectrum ($|W|^2$) for deseasonalised time series of T, P, VPD, ETo, NAO and NCP during the period 2002-2022. The COI region is below the thick black line. Statistically significant areas at the level of $\alpha = 0.05$ are indicated by a thin black line

Opóźnienia w odpowiedzi NDVI na zmiany warunków meteorologicznych

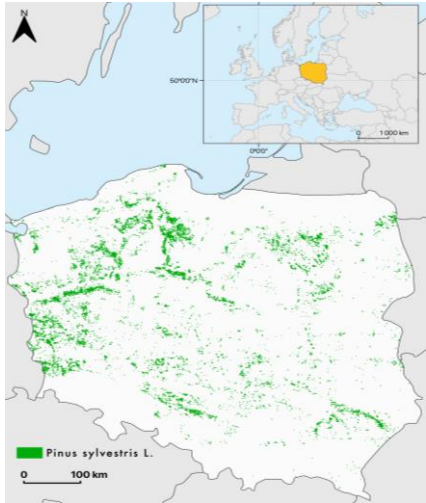


Wavelet Coherence power spectrum (colour scale) between deseasonalised time series of NDVI and T, P, ETo and NAO for broadleaved forest and coniferous forest during the period 2002-2022. Colours range from blue (low correlation) to yellow (high correlation). Arrows indicates the phase difference between signals: right arrows – series are completely in phase, left arrows – series are out of phase. The COI region is below the thick black line. Statistically significant areas at the level of $\alpha = 0.05$ are indicated by a thin black line



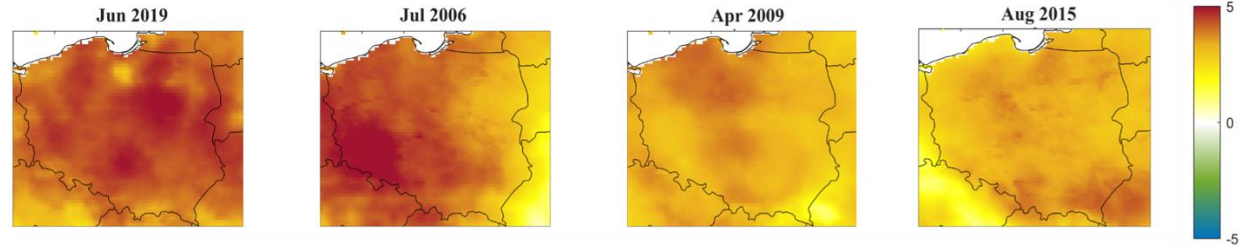
Correlation coefficients between deseasonalised time series of NDVI and T, P, VPD, ETo and NAO for broadleaved forest and coniferous forest. The pairs of data sets are correlated with appropriate time lag of 0 to 36 months. Statistically significant correlations at the level of $\alpha = 0.05$ are indicated by a circle

Wpływ silnych susz na produktywność netto (NPP) drzewostanów sosnowych

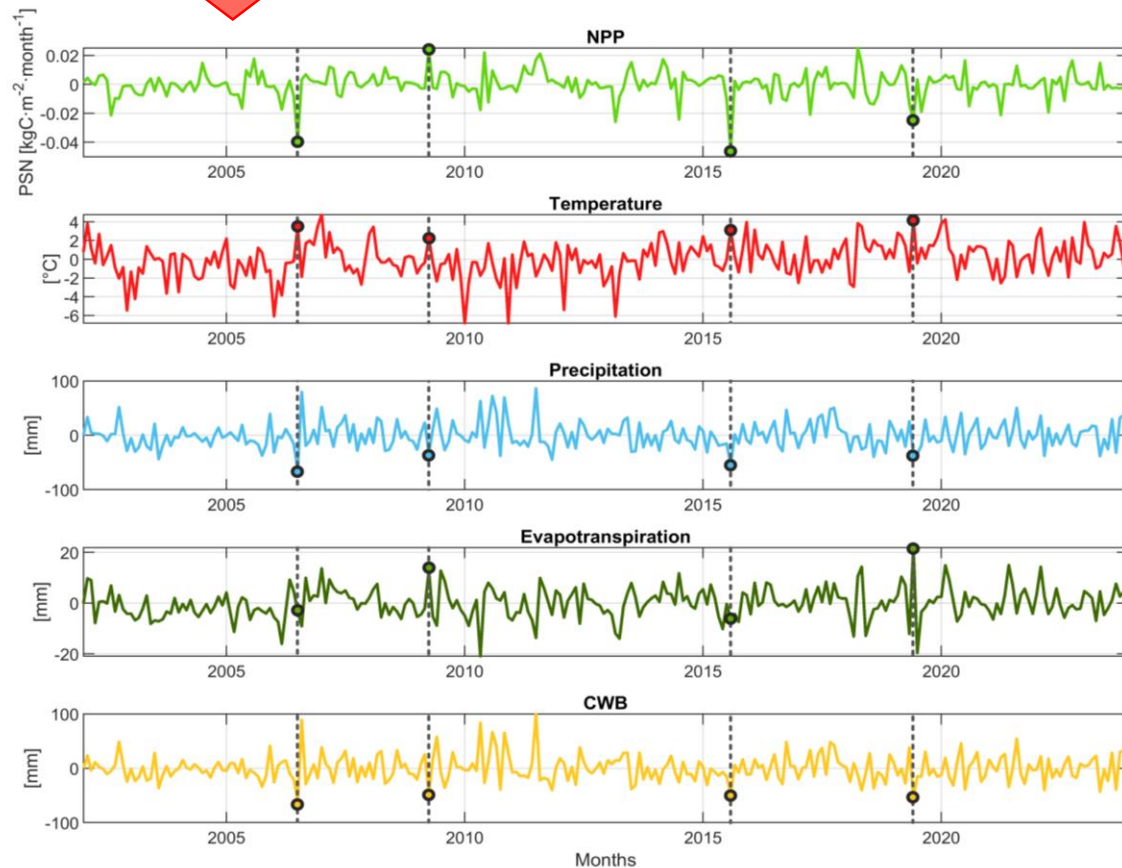


Spatial distribution of pine mask in MODIS 500 × 500 m grid cells.

$$ZT_dt_{m,i} = \frac{T_dt_{m,i} - \mu_{T_dt_{M,i}}}{\sigma_{T_dt_{M,i}}}$$



Spatial distribution of the $Z_dt_{m,i}$ index (sum of detrended T and detrended CWB) for selected months with the most extreme drought events in Poland in the period 2002-2023. The maps show top four of the most severe drought events (June 2019, July 2006, April 2009 and August 2015), ranked in descending order based on the area-averaged values of Z_dt_m . The values are expressed in standard deviation units.



Multi-annual course of area-averaged monthly z-scores: ZNPP and meteorological elements (ZT, ZETo, ZP and ZCWB) in pine-masked pixels in Poland in the period 2002-2023. Dots and dashed lines indicate the selected severe droughts.

2006

	july	+1 month	+2 months	+3 months
T	-0.74	-0.21	-0.74	0.31
P	0.51	0.31	0.57	0.06
ETo	0.4	0.19	0.51	0.07
CWB	-0.06	0.04	-0.15	-0.05

2009

	april	+1 month	+2 months	+3 months
T	0.76	-0.09	0.02	-0.7
P	0.4	0.27	0.01	-0.26
ETo	0.26	-0.05	-0.05	-0.3
CWB	0.13	0.24	0.05	0.01

2015

	august	+1 month	+2 months	+3 months
T	-0.75	-0.55	0.55	0.69
P	-0.2	0.22	0.64	0.23
ETo	0.48	0.56	-0.07	-0.41
CWB	-0.67	-0.39	0.63	0.62

2019

	june	+1 month	+2 months	+3 months
T	-0.68	-0.62	-0.37	0.03
P	0.33	0.28	0.15	0.18
ETo	0.4	0.18	0.13	0.38
CWB	-0.05	0.13	0.04	-0.21

Correlation coefficients with 0-, 1-, 2-, and 3-month delay, between ZNPP and ZT, ZETo, ZP, ZCWB, from all pine-masked pixels, for July 2006 (a), April 2009 (b), August 2015 (c), and June 2019 (d). All the coefficients are statistically significant ($\alpha=0.05$).

Dziękuję za uwagę!

Pytania? Skontaktuj się z nami!

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Więcej do przeczytania:



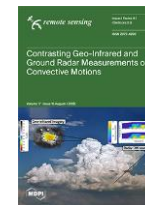
Kulesza K., Hościło A., 2023. Influence of climatic conditions on NDVI variability in forest in Poland (2002-2021), **Meteorological Applications**. DOI: 10.1002/met.2156.



Kulesza, K. Hościło, A., 2024. Coherency and time lag analyses between MODIS vegetation indices and climate across forest and grasslands in European temperate zone, **Biogeosciences**. DOI: 10.5194/bg-21-2509-2024.



Kulesza, K. Hościło, A., 2024. Temporal Patterns of Vegetation Greenness for the Main Forest-Forming Tree Species in the European Temperate Zone, **Remote Sensing**. DOI: 10.3390/rs16152844.



Kulesza, K.; Hawryło, P.; Socha, J.; Hościło, A. 2025, How Reliable Are the Spectral Vegetation Indices for the Assessment of Tree Condition and Mortality in European Temporal Forests?, **Remote Sensing**, 17, 2549. DOI: 10.3390/rs17152549.



Kulesza, K., Zając, O., and Hościło, A.: Extreme droughts' impact on Scots pine net primary productivity in the European temperate zone in the period 2002–2023, **EGU sphere** [preprint], <https://doi.org/10.5194/egusphere-2025-2770>, 2025.

