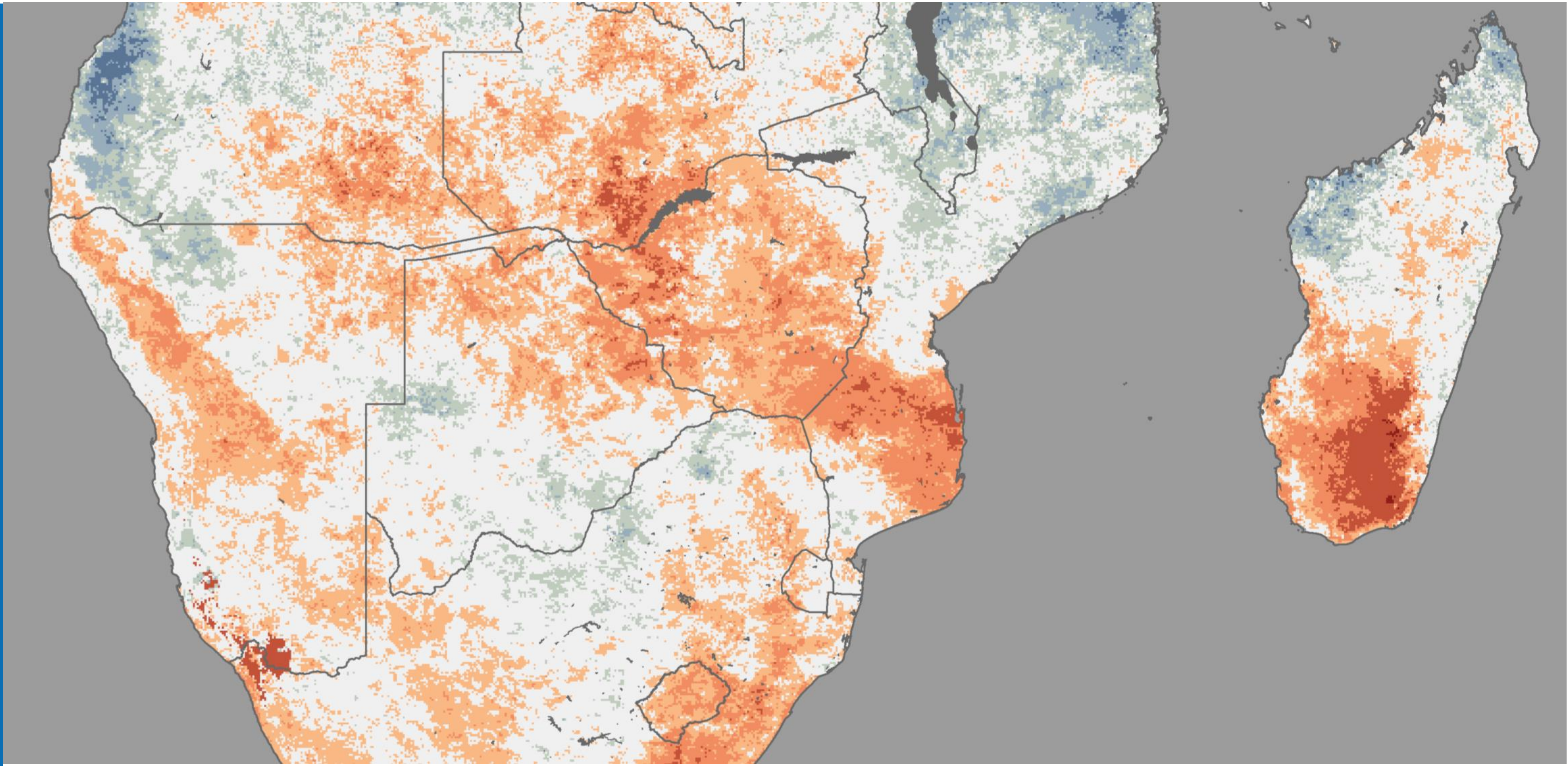
WFP

World Food Programme



SAVING LIVES
CHANGING LIVES

A Combined Drought Index: Concept and Practice

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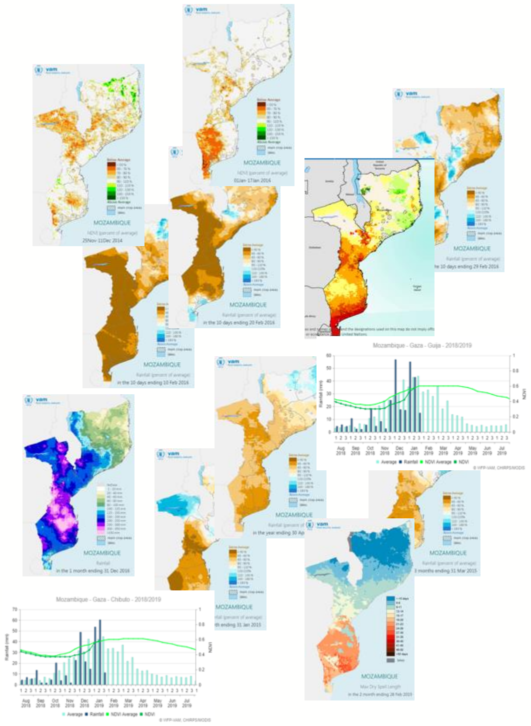
Motivation

WFP World Food Programme

While drought is a very complex phenomenon, decision makers and the general public require a simplified way to identify areas that have been most affected by a drought event.

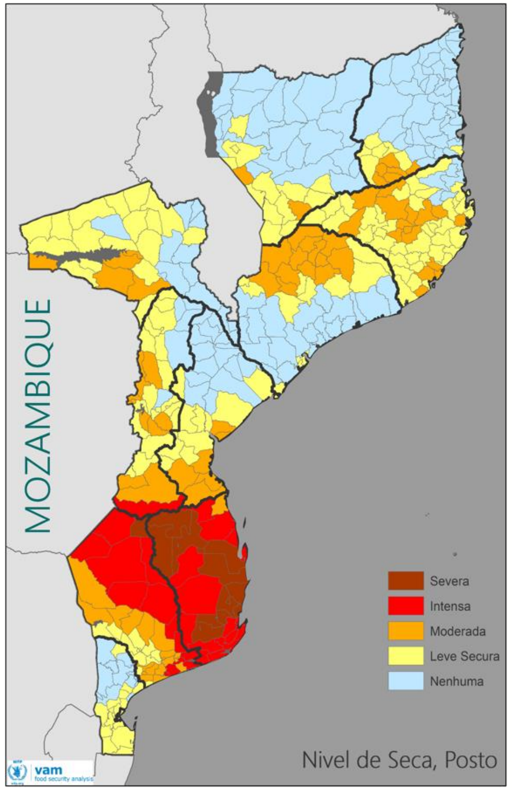
Multiple indicators / variables



Analysts

Combine multiple variables into a Drought Index

Top level Indicator



Decision Makers

Motivation

Objective:

An Index that conveys the performance of the growing season in an easy-to-understand numerical scale, e.g. 0-100.

The proposed index is built on the key variables of the water cycle available as gridded variables:

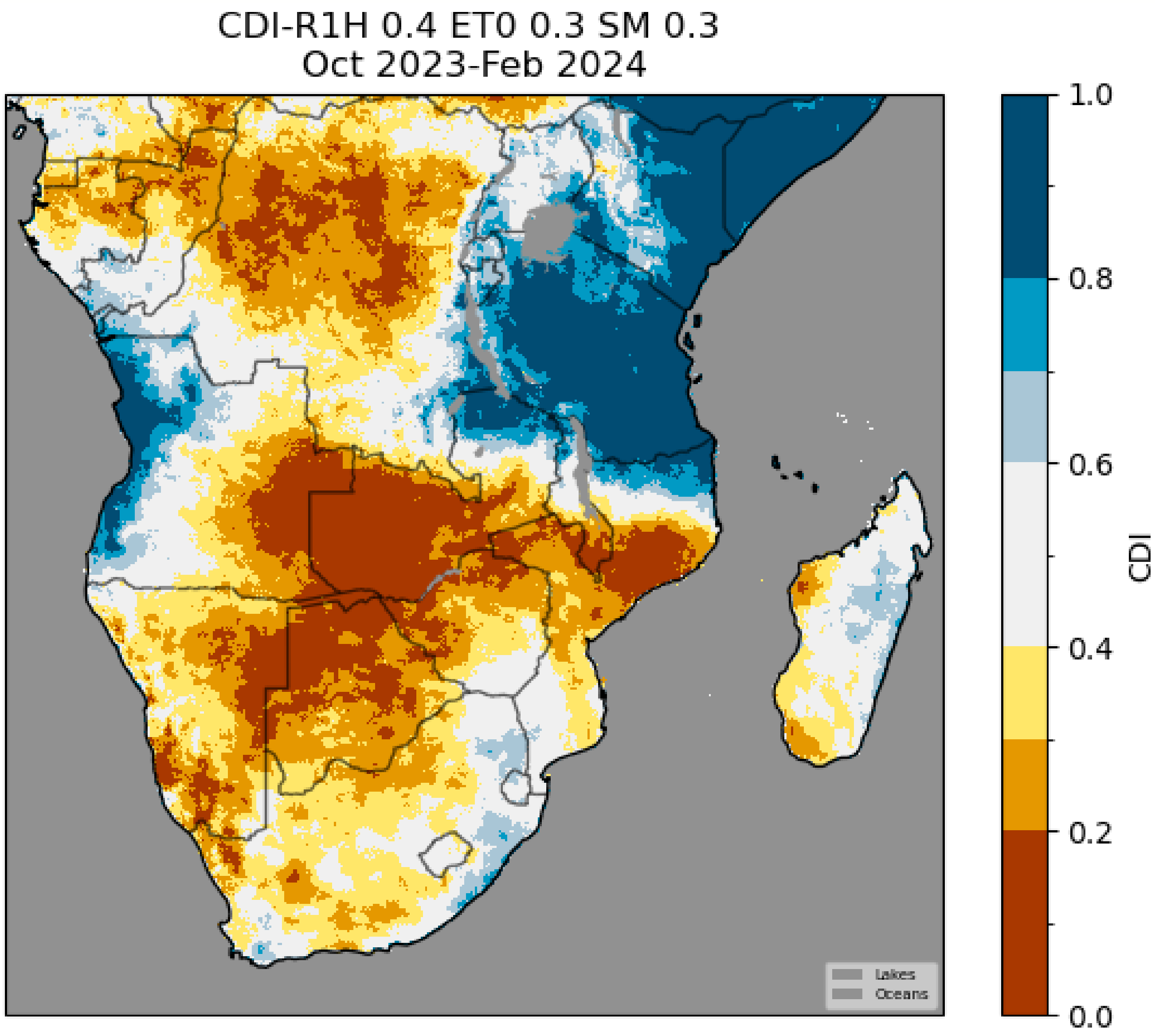
- Rainfall
- Reference (potential) evapotranspiration
- Soil moisture.

Rainfall representing water availability, **reference evapotranspiration** representing water demand and the **soil moisture** stored water.

Motivation

The index should be available for each time step of the growing season representing the combined state of the water variables at that moment along the season.

It should also be available as an integrated amount over a number of time steps or the full season.



Calculation

The index is derived using a monthly time step.

The monthly time step variables are converted to an anomaly, i.e. a measure of how far from the "usual" their values are. This is built from information for the specific month for which the anomaly is derived.

$$\text{Rainfall} \Rightarrow Q_{rainfall}$$
$$\text{Ref Evapotranspiration} \Rightarrow Q_{ref.ET}$$
$$\text{Soil Moisture} \Rightarrow Q_{soil\ moisture}$$

Which anomaly should we choose? The two obvious candidates:

Percentiles and **Standardized Anomalies**.

Calculation

Both convey where the variables “sit” in the historical distribution of values.

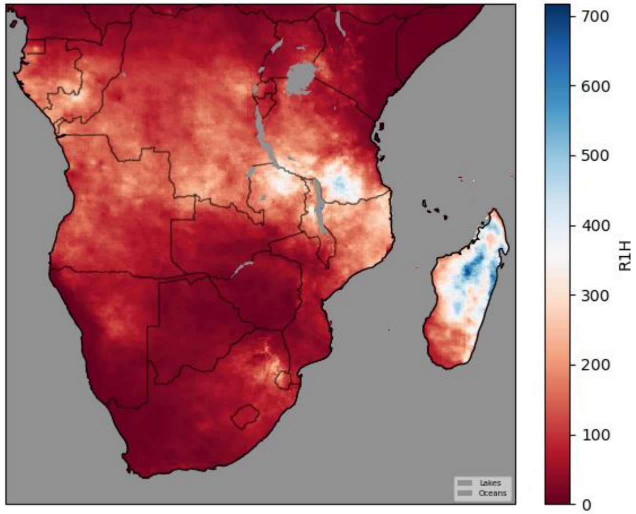
- **Percentile**: In a scale of 0-100, where 0 = lowest, 50 = midpoint, 100 = highest
- **Standardized Variable**: distance from mean in standard deviations [-4 to +4]

The percentile (noted **Q**) is preferred as the 0-100 scale is easier to understand by non specialists.

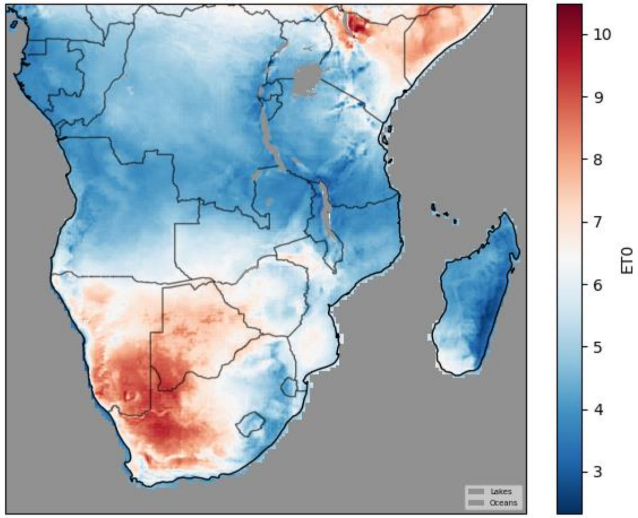
$$\mathrm{CDI} = f\left(\mathrm{Q}_{rainfall}, \mathrm{Q}_{\mathrm{ref.ET}}, \mathrm{Q}_{\mathrm{soil\ moisture}}\right) \qquad (1)$$

The monthly value of the index is then derived by combining these percentiles.

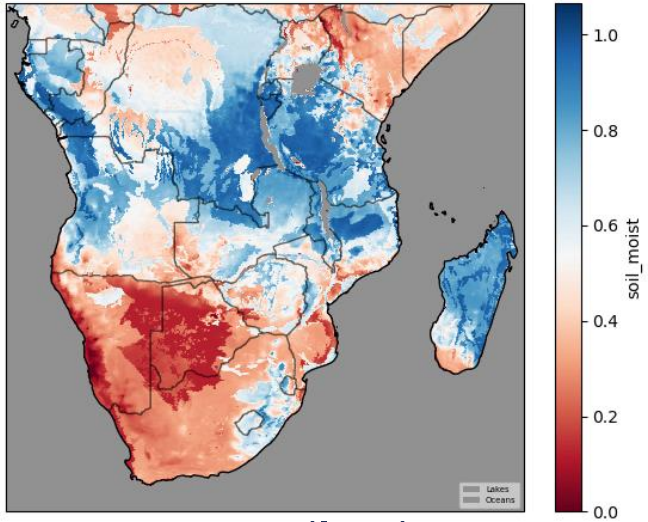
Calculation



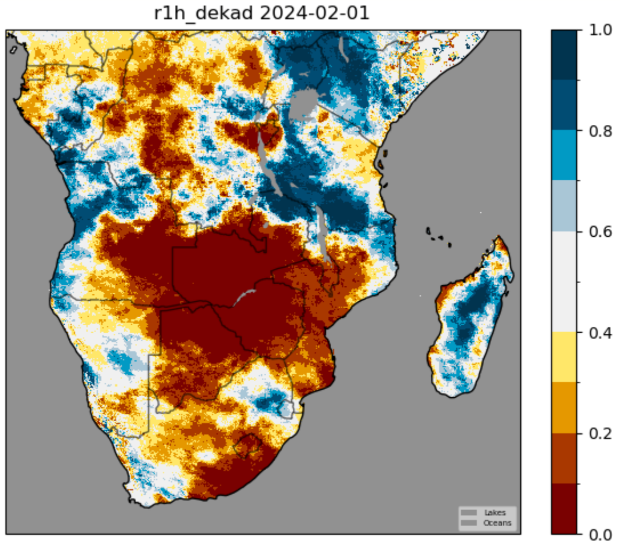
Rainfall

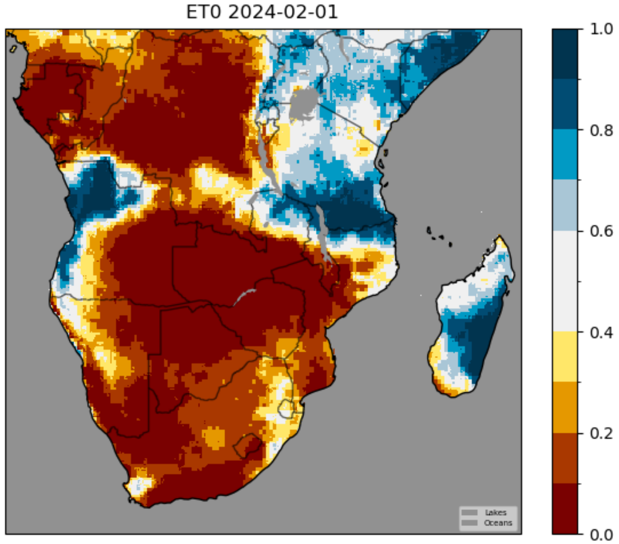


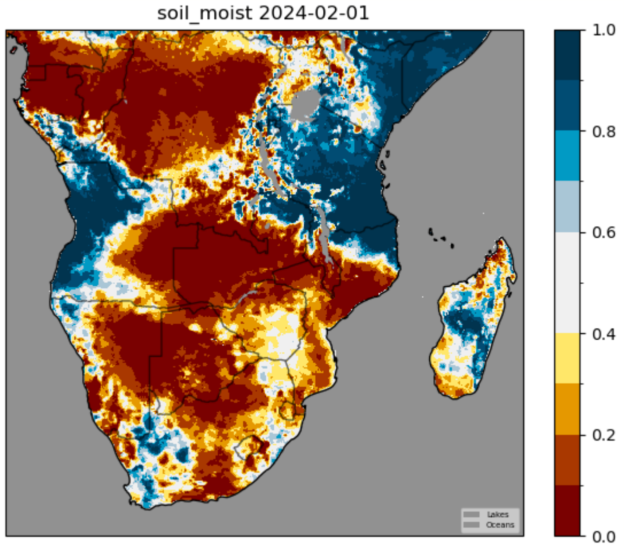
Ref ET



Soil Moisture







Individual variables for Feb 2024 converted to Percentiles

Calculation

How do we combine these percentiles? Simplest is to use a weighted mean of the percentiles. Percentiles can't be averaged directly, they have to be transformed to logits:

$$\theta_{\text{rainfall}} = logit\,(\,\text{Q}_{\text{rainfall}}) \qquad logit(\text{Q}) = ln\,(\text{Q}/(1-\text{Q}))$$

Repeat for other variables, then weighted mean:

$$\theta = \sum w_i * \theta_i$$

The weights (which add to 1) are **importance** weights and reflect the relative importance we attach to each variable. Currently we have:

W$_{\textbf{rainfall}}$ = 0.4

W$_{\textbf{refET}}$ = 0.3

W$_{\textbf{soil moisture}}$ = 0.3

Rainfall is weighted more since it is the driver variable and is derived from actual observations, the other two being modelled estimates

Calculation

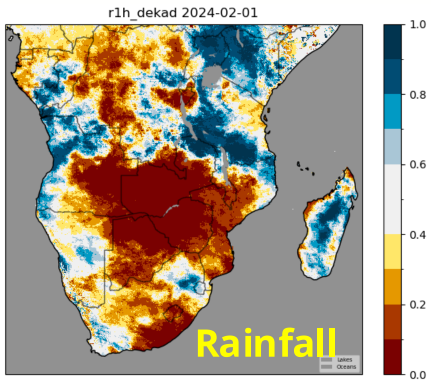
Once logits are combined, we have to go back to a 0-100 scale, because that is how we convey the performance of the variables.

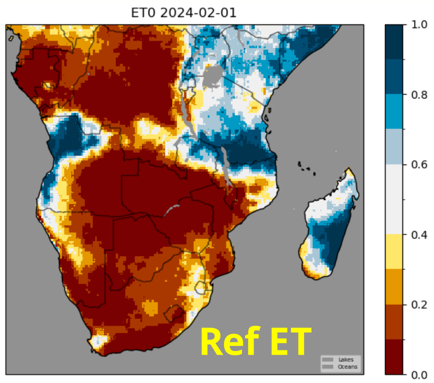
We do this using the **inverse logit** function.

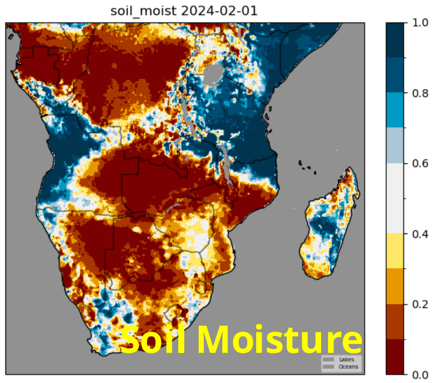
$$CDI = 100 * \mathrm{invlogit}(\theta)$$

$$CDI = 100 * \frac{\exp(\theta)}{1 + \exp(\theta)}$$

Calculation





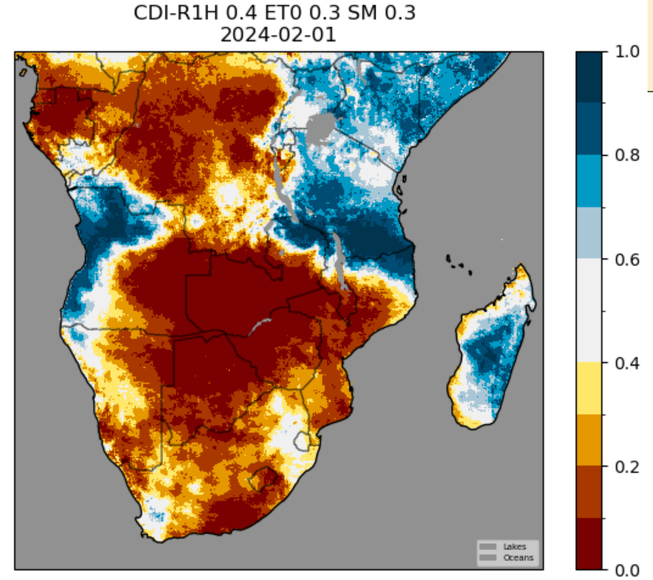


Weighted Logit

Logit Rainfall * 0.4 + Logit RefET * 0.3 + Logit SM * 0.3 =

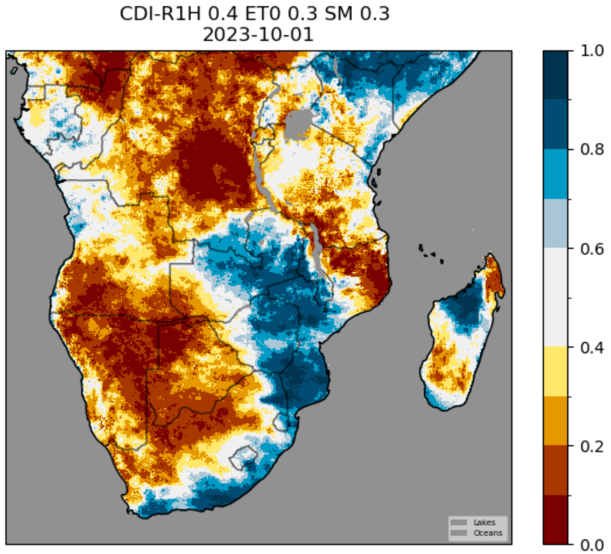
InvLogit

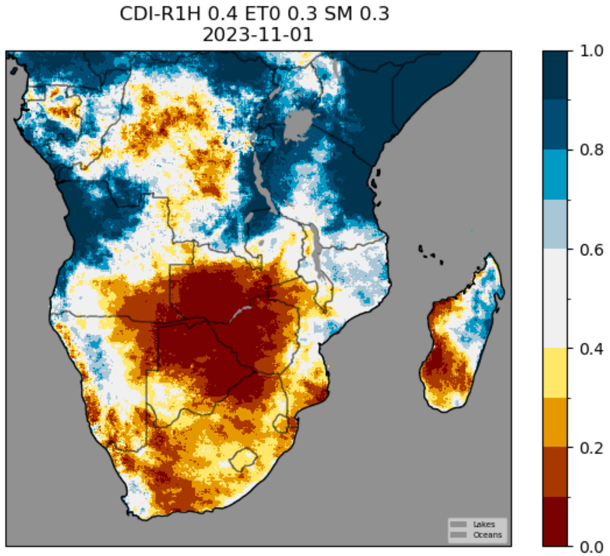
CDI February 2024

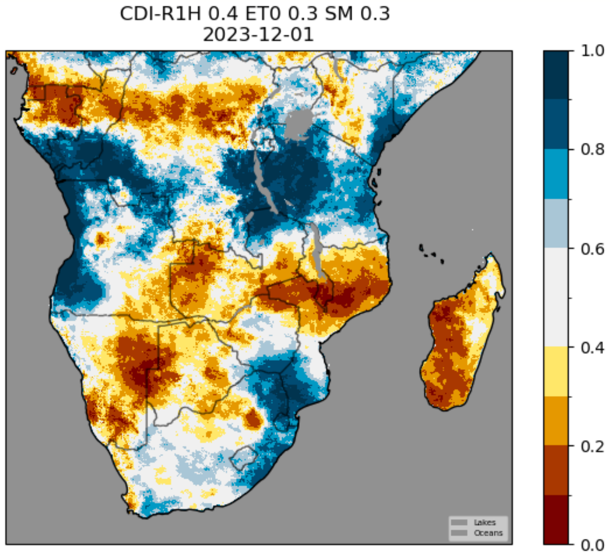


Seasonal Index

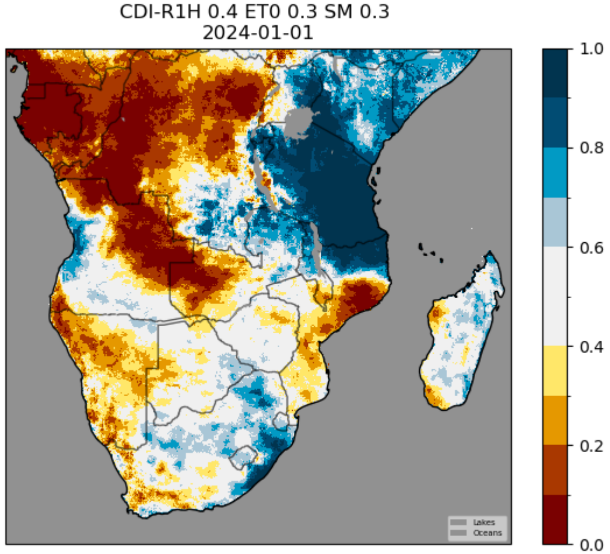
Seasonal Index

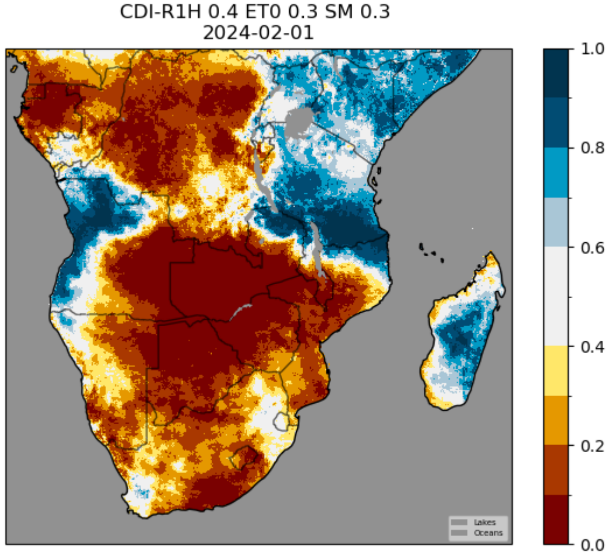






Once we have the monthly CDIs, how can we form a seasonal CDI?





Seasonal Index

The interest is to derive a seasonal CDI, that can translate the performance of the whole season to date, and not just at a specific point in time.

We integrate the monthly CDIs through the season, using time varying monthly weights.

The seasonal weights ***S*** should reflect the importance of each month in the rainfall season. E.g. February is more important than October.

Seasonal Weights

The seasonal weights reflect the contribution of each month to the growing season.
A simple way to define them is:

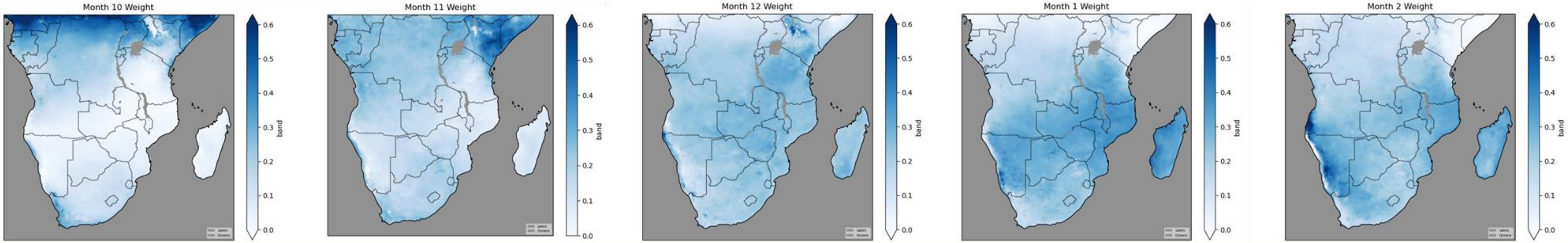
$$S_i = Weight_{month\ i} = \frac{\overline{Precip_{month\ i}}}{\overline{Precip_{total}}}$$

They are derived from the long term mean rainfall and are the proportion of the seasonal rainfall that (on average) falls in each month. The weights always add to 1.

"Seasonal rainfall" is the rainfall for the whole season (Oct-Apr for Mozambique) or for any period the user is considering (like a shorter season to date, Oct-Feb, or a three-month period like JFM. Pixel level seasons can be considered as well.

Seasonal Weights

In the context of Southern Africa, October contributes a much smaller amount to the index compared to February, since February is a much rainier month. All calculations are pixel based, so this scheme accounts for the variability in rainfall seasonality that may exist across the region.



Southern Africa Monthly Weights October - February

Seasonal Index

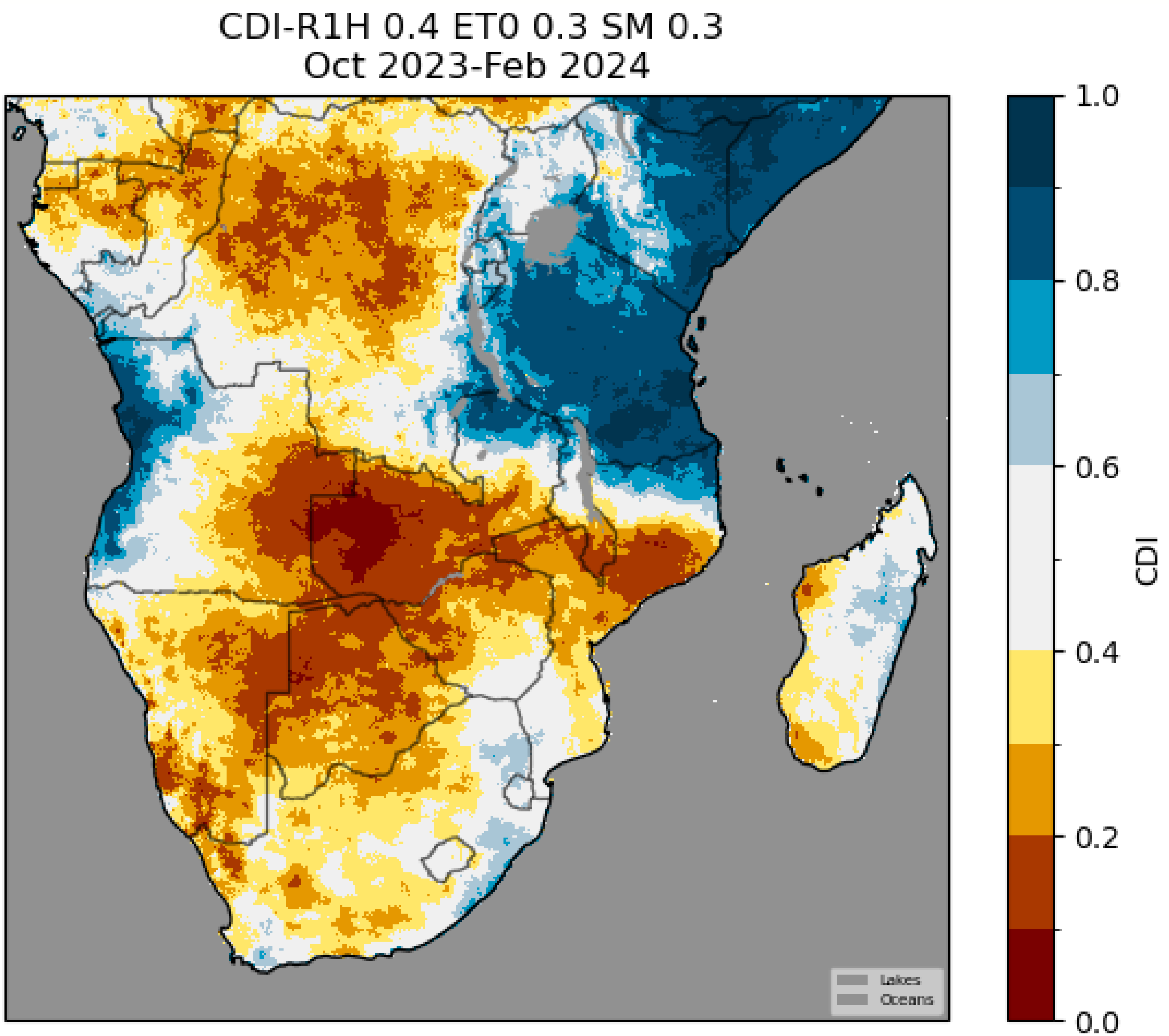
$$\theta_{\text{CDI month i}} = logit\,(\,\text{CDI}_{\text{month i}})$$

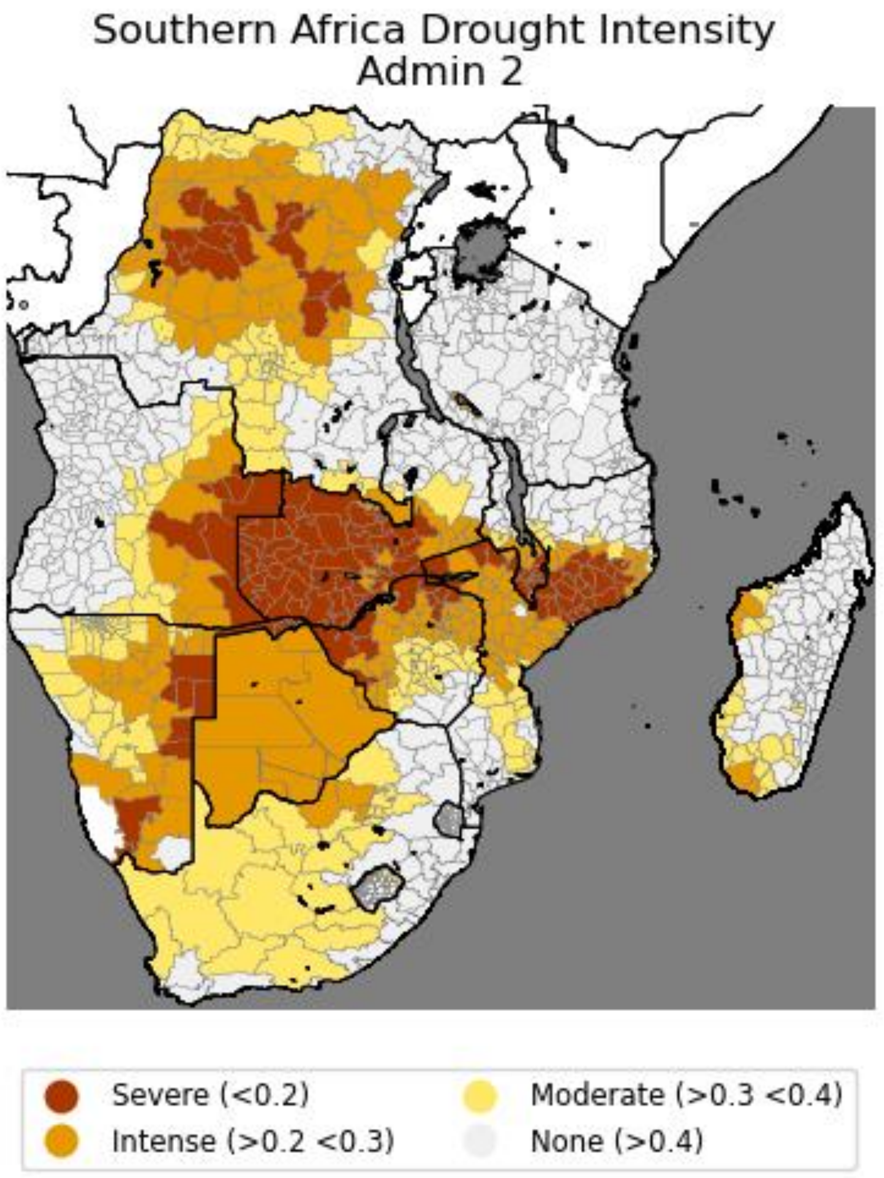
$$\theta_{\text{seasonal}} = \sum \text{s}_i * \theta_{\text{CDI month i}}$$

$$\text{CDI}_{\text{seasonal}} = 100 * \text{invlogit}(\theta_{seasonal}\,)$$

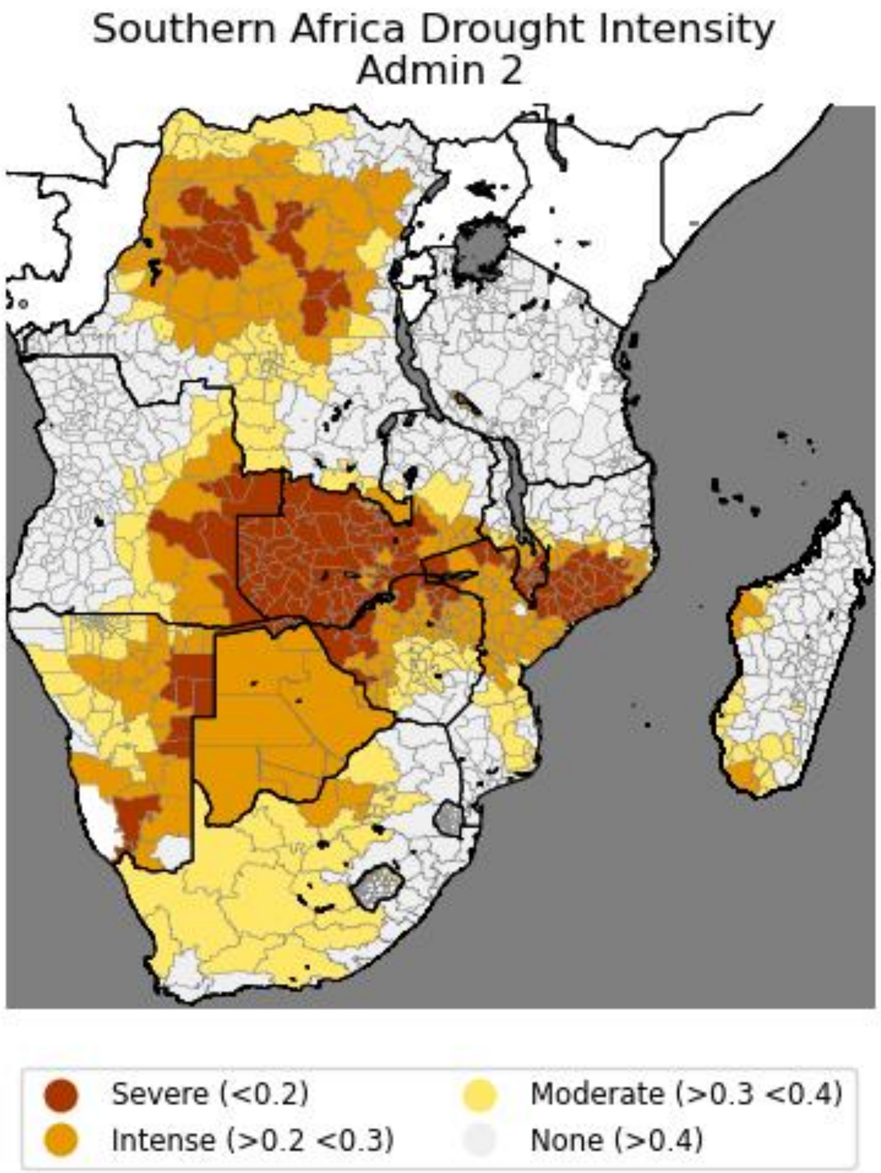
The weighted sum of the monthly CDI is done through a Logit / InvLogit conversion

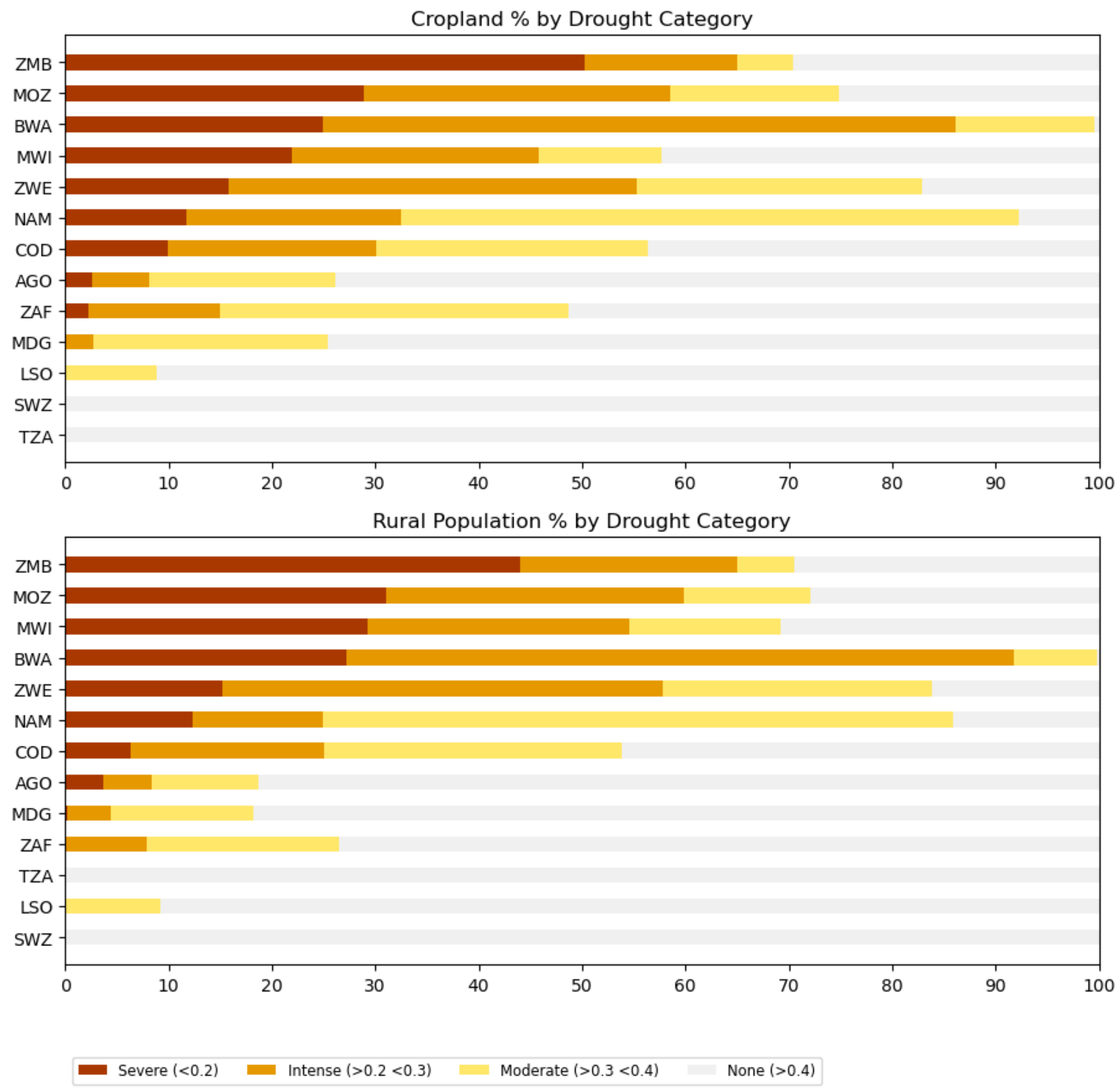
Practical Applications



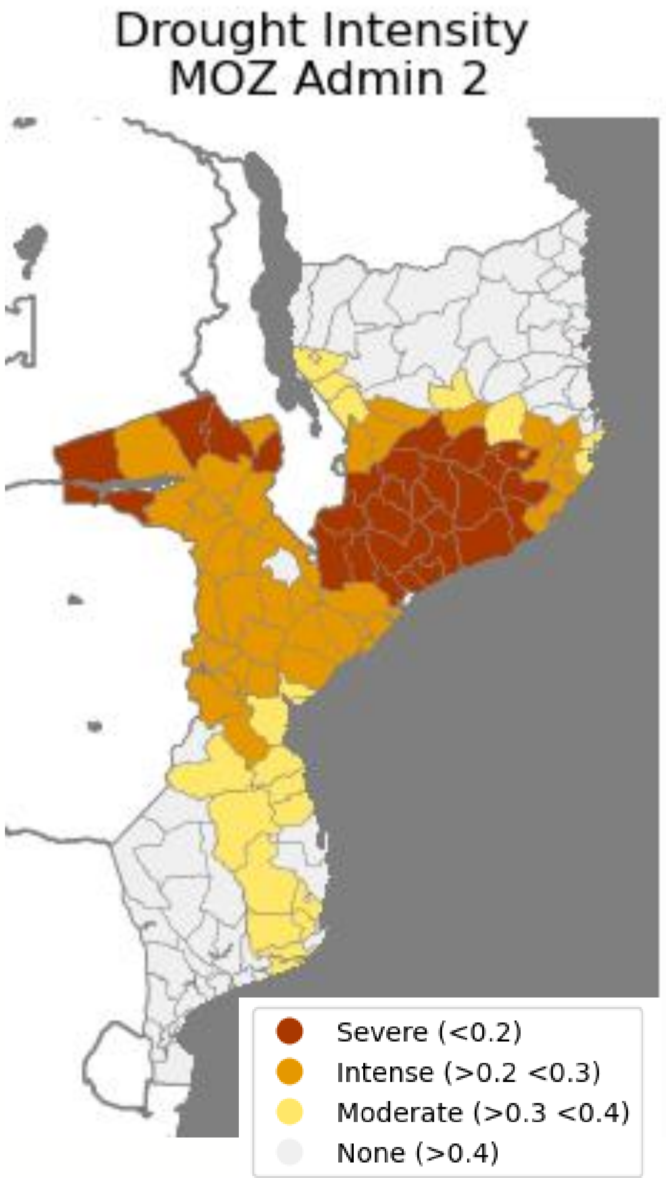


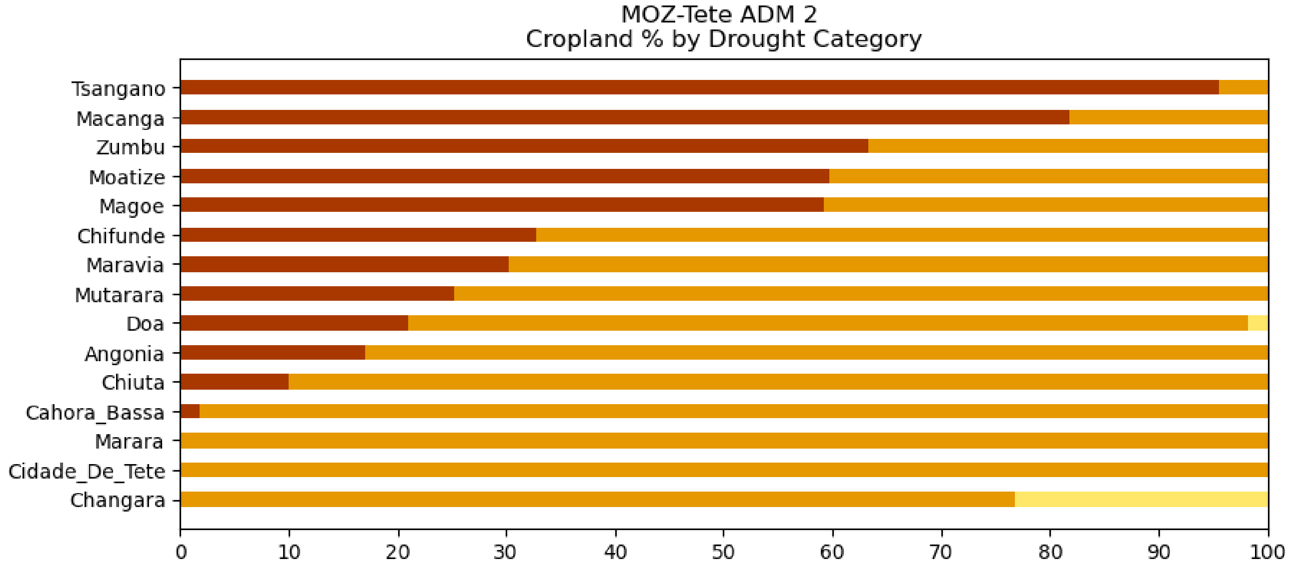
Practical Applications

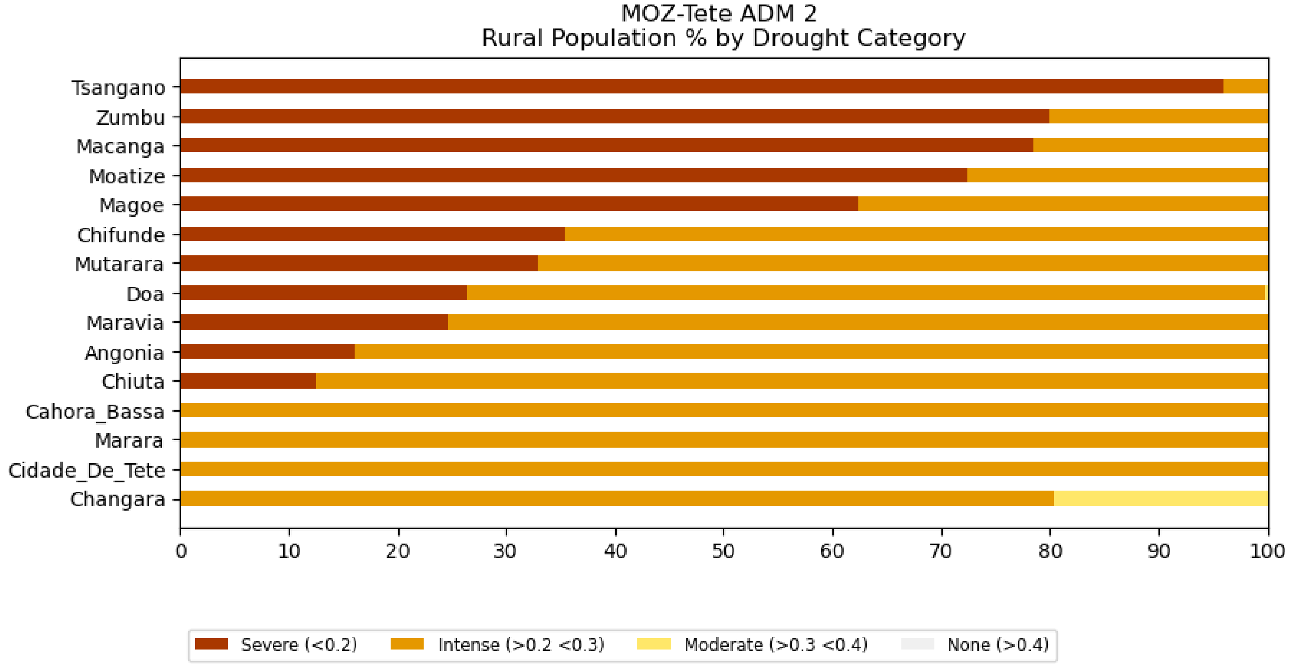




Practical Applications







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