MOZAMBIQUE:
A Climate Analysis

Foreword

This document presents a climate analysis for Mozambique, based on analyses of medium term records (36 years, 1981 to 2016) of precipitation, vegetation and temperature.

The analysis has three main themes – averages, variability and trends. Averages describes the broad climate features. Inter-annual variability describes high frequency, year-on-year changes. Trends evaluate the degree and direction of longer term variations.

Specific analysis for the start, end and length of rainfall season are included, so as to provide a detailed account of the patterns and tendencies of change in growing season timings.

The effects of ENSO phases is also analysed through the mapping of the variations in rainfall between El Niño-La Niña dominated seasons versus neutral seasons.

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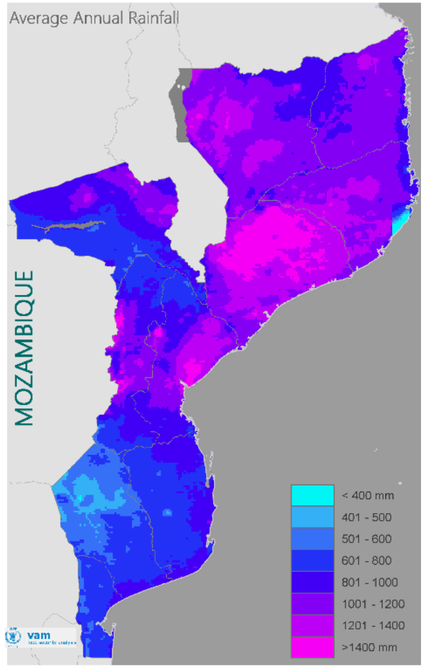
Produced in the framework of the
IFAD-WFP Joint Climate Analysis Partnership

Mozambique Climate Analysis

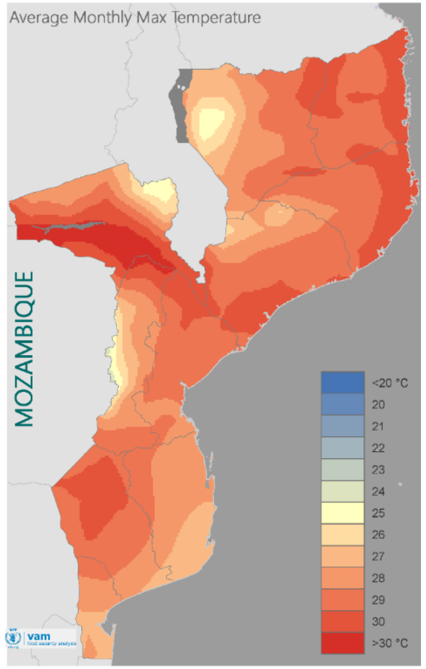


Rainfall: CHIRPS
Near Global gridded rainfall data.
10 day time step, 5Km resolution
1981-present

Consistency Check

Average Variability Trends Seasonal Trends	Average Variability Trends Seasonal Trends

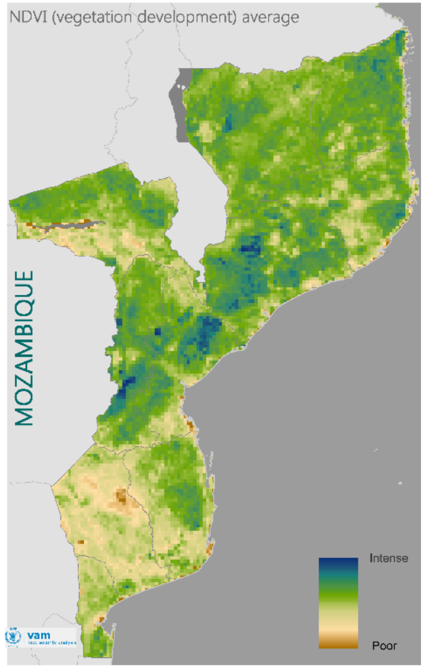
Average Variability Trends Seasonal Trends



Temperature: CRU
Global gridded temperature data.
Monthly (mean Tmax, Tavg, Tmin)
0.5 deg resolution
1981-present

The study utilized 3 gridded data sets of rainfall, temperature and vegetation. The basic work consisted of deriving for each of the three variables:

- A characterization of the average pattern across Mozambique.
- An analysis of the temporal changes for all-country and sub-national units
- Mapping of trends for each variable for the study period. Mapping of trends on a monthly basis and definition of regions with similar seasonal trend profiles
- Analysis of rainfall, vegetation and growing season patterns in each ENSO phase



Vegetation: NDVI
Global GIMMS NDVI.
15 days, 8Km resolution
1981-2015

The derived characteristics were analyzed looking for consistency between patterns detected from the rainfall analysis (and temperature to a lesser degree) and those patterns detected in the vegetation data.

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SUMMARY

The analysis used a 36 year long gridded rainfall record (CHIRPS) from 1981 to 2017, a gridded temperature record covering the same time span and a satellite vegetation index data set also covering the same period. The rainfall data enabled the analysis of 36 seasons in Mozambique, and an identical number for temperature. The vegetation data set was somewhat shorter, ending in 2015 and enabling analysis of 34 growing seasons.

The rainfall season in Mozambique lasts from October to May with small amounts also possible outside this bracket. Most of the rainfall comes between November and April. The wettest period within the season is December-January with January being the wettest month across the whole country. There is a clear south to north increase in average rainfall amounts and a less well marked increase from interior to coastal areas. Driest provinces are Maputo, Gaza and Tete. **SLIDES 13-14**.

An initial analysis of the temporal variations of rainfall for the study period 1981-82 to 2016-17, revealed the absence of a defined long term trend for the country average rainfall; the country has experienced broad periods with distinct rainfall behaviour; in particular, the driest period in the recent past from 1990/91 to 1995/96, that was followed by the wettest period in the same record lasting from 1996/97 to 2000/01. Since then rainfall has fluctuated around the long term mean. A province level analysis shows highlights different flavours of this overall behaviour with the northern provinces displaying considerable departure from the country wide picture. **SLIDES 15-16**

Overlaid on these multi-year changes, the country experiences very considerable inter-annual variability particularly in the drier areas of the south. **SLIDE 17**

While there is no overall rainfall trend considering the country as a whole, a full mapping of rainfall trends shows significant variations across the country: trends in seasonal rainfall appear positive (increasing) in the southernmost third and western areas of the country and moderately decreasing in the northern provinces. An analysis of the variation of rainfall trends along the season indicates that the increase in seasonal rainfall in the south and west of the country mostly arises from increases in December and January, already the wettest period of the season. On the other hand, the decrease in seasonal rainfall in the centre and north of the country are mostly due to decreases in early season rainfall (October-December). **SLIDES 18-20**

Similar patterns are seen in the longer term variations in the number of rain days. Here there is a noticeable decreasing trend in the number of rain days at country wide level. This decrease again shows considerable geographical variations being much more pronounced in the four northern provinces. Elsewhere, trends in seasonal rain days are moderately positive. Again the tendency is also for the reduction in the number of rain days to be concentrated in the earlier stages of the season (October-December). **SLIDES 21-24**

Analysis of the occurrence of heavy rainfall days, shows these to be more prevalent in Zambezia province, as expected since it is the wettest area of the country. These heavy rainfall events have a moderate tendency to decrease in the northern third of the country, mirroring the trends in seasonal rainfall and number of raindays. On the other hand, dry spells are longer but also more variable in the drier areas of the country – no significant trend is noticeable in the length of dry spells across the country. **SLIDES 25-30**

Timings of growing season derived from modelled moisture indicators shows areas of shortest growing season length in Gaza and Tete provinces, mostly arising from a combination of later start and earlier end of suitable moisture conditions. Again Gaza is the region with a very marked inter-annual variability in growing season length. No tendency in growing season length is noticeable across most of the country, except for large areas of the Nampula province. **SLIDES 31-33**.

The impact of the long term rainfall trends is reflected in the response of vegetation cover, which shows a moderate decreasing tendency at the national scale. However, this decrease is much more marked in the northern provinces – here vegetation cover shows marked decreasing trends in the early stages of the season, matching corresponding patterns of decreasing rainfall and number of rain days. **SLIDES 34-37**

A major driver of inter-annual variability is ENSO, in its two phases, warm (El Niño) and cold (La Niña). The impact of these two phases was examined by comparing patterns in seasons under each phase with neutral seasons. El Niño seasons are provinces on balance enjoy wetter early season condition during El Niño. Rainfall reductions are most pronounced in the January to March period. In contrast, La Niña seasons have a positive influence on rainfall, again more pronounced in the south and centre and during January to February. The El Niño rainfall patterns are well reflected in the vegetation patterns for the same phase and periods. The maps provide a ready identification of the areas most affected by ENSO impacts, their timing and intensity. **Slides 38-46**

Temperature patterns show weak trends in Tmax and Tmin. Tmax increases are mostly concentrated within the rainfall season and are more marked in southern and central regions; Tmin shows decreases in the south of the country mostly in the second half of the rainfall season. **Slides 47-51**.

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BASIC MAPS

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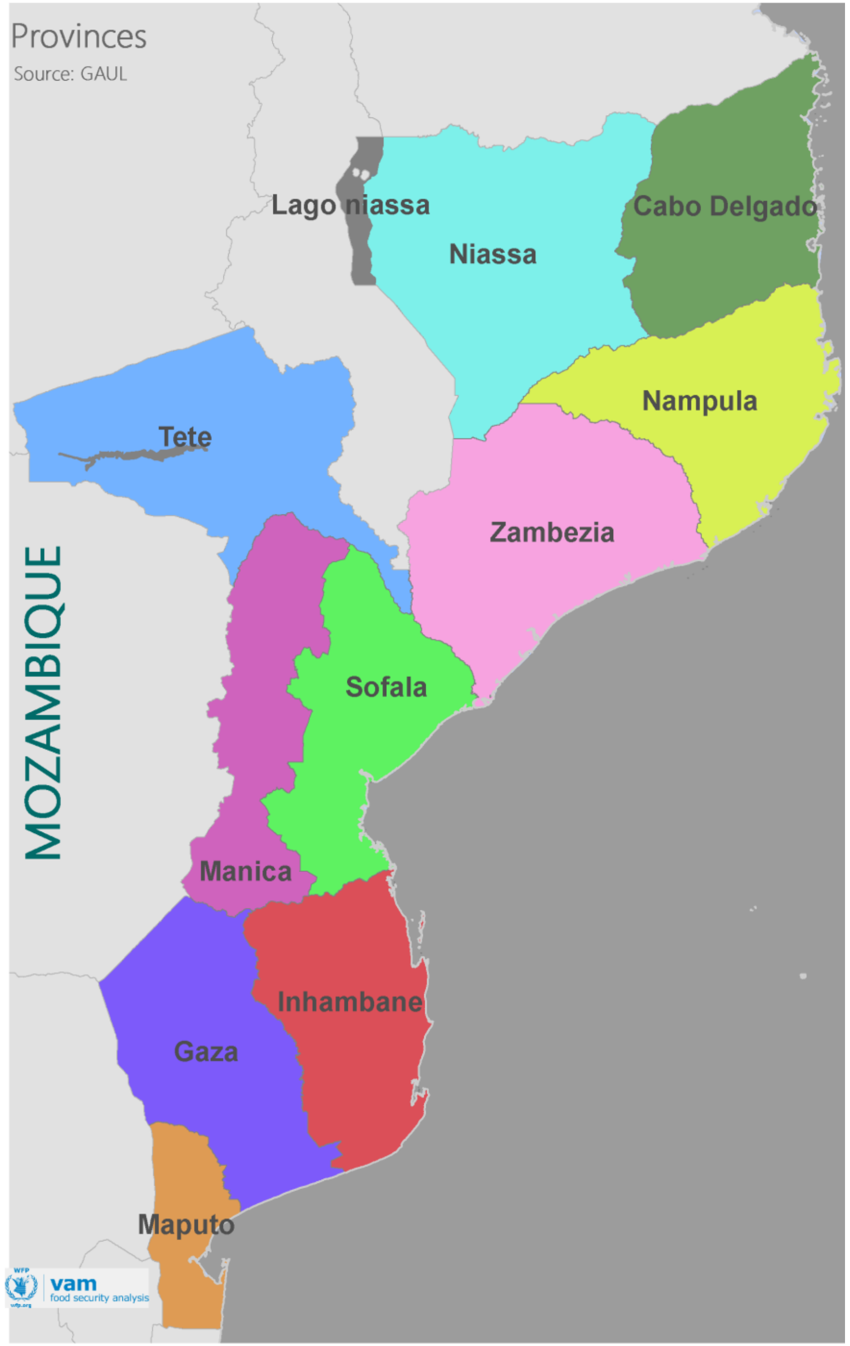
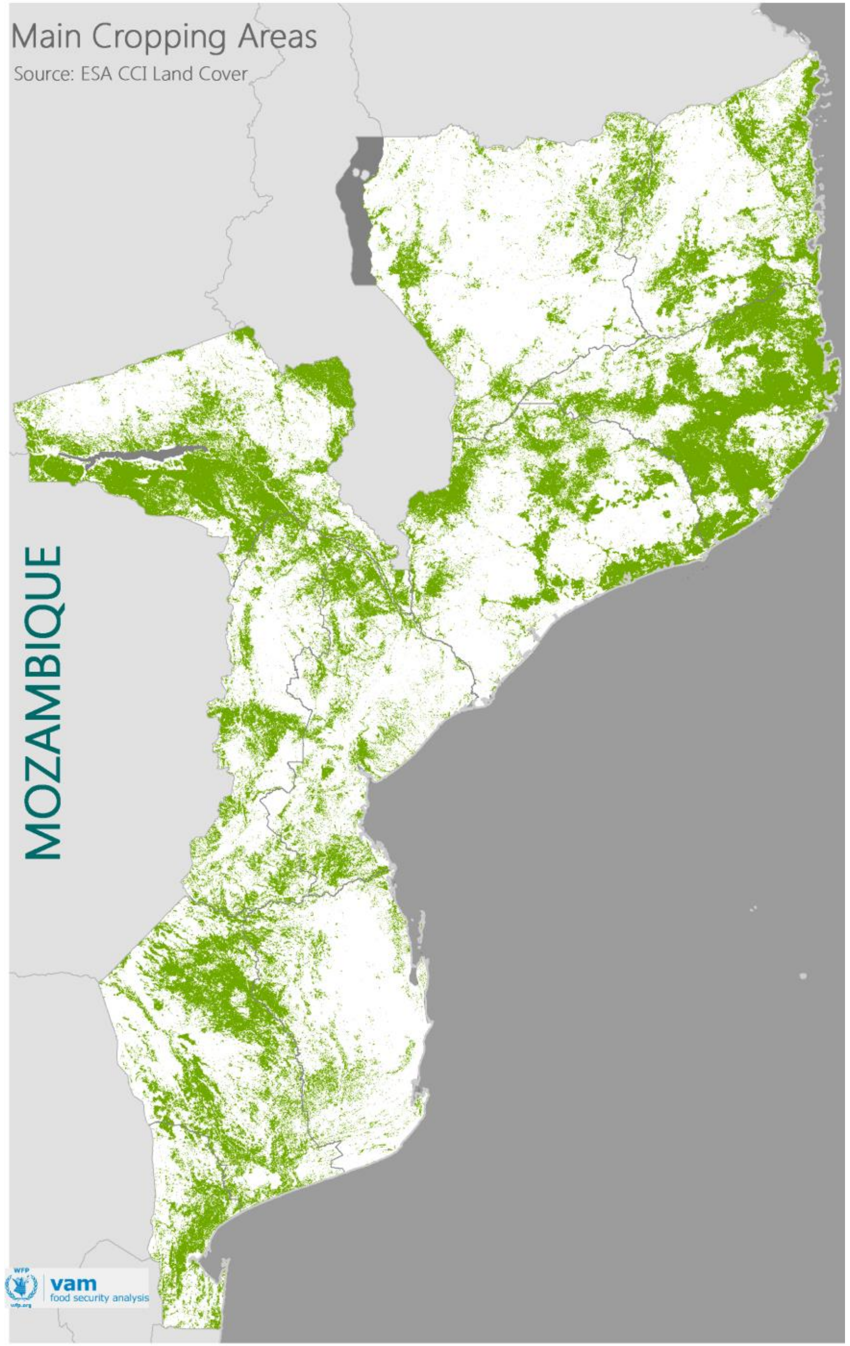
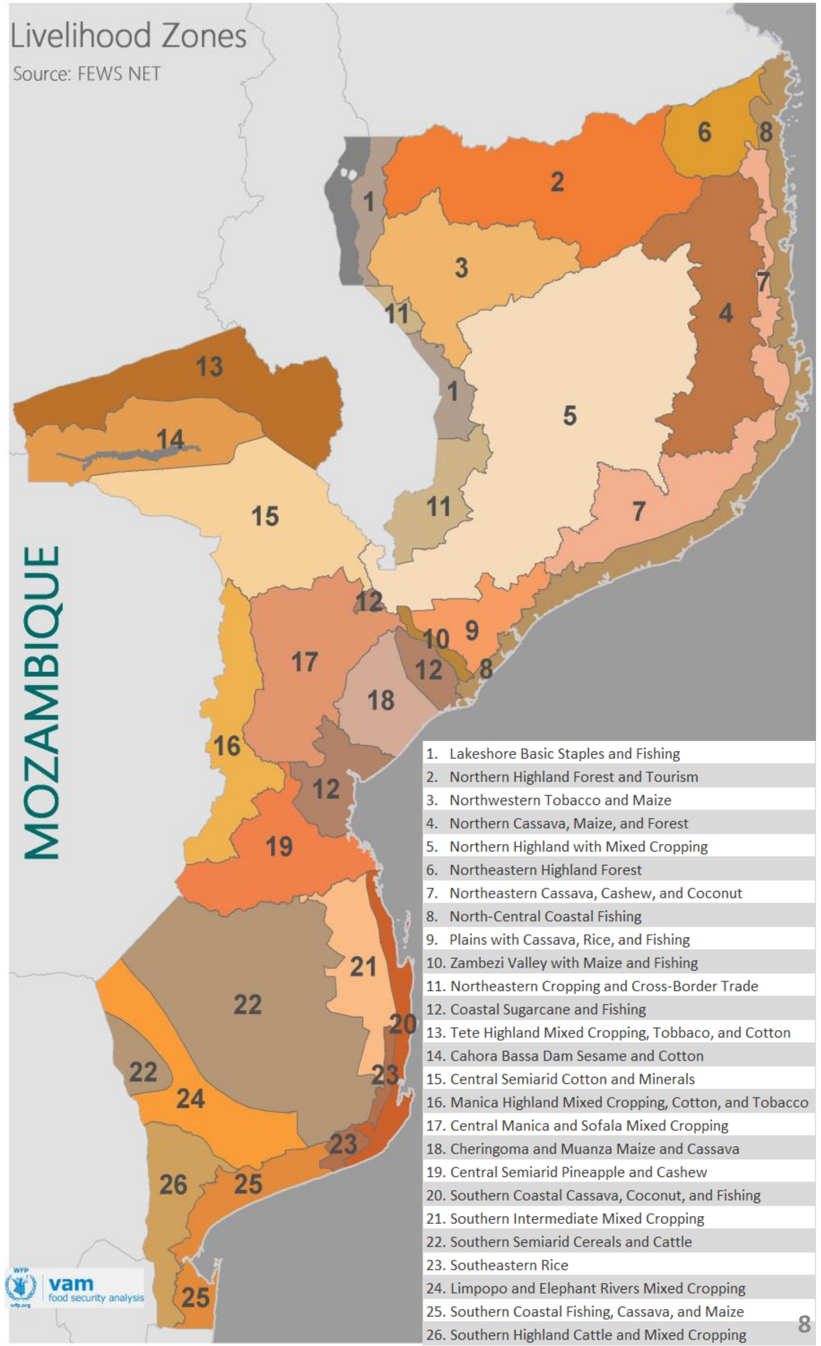






Province Level Main Features

Maputo

Southernmost province and one of the driest as well. Characterized by a relatively long season of low irregular rainfall. No noticeable trend in seasonal rainfall or rain days at provincial level. Fairly early start of the growing season leading to long growing seasons (up to 7 months in southern areas). Moderate increasing trend in seasonal vegetation cover.

ENSO impacts are relatively modest, with El Niño leading to lower than average rainfall and vegetation cover and shorter growing seasons. Rainfall is enhanced in La Nina seasons but mostly only during January to March.

Inhambane

A wetter province with high inter-annual variability and a tendency for increasing seasonal rainfall. No trend on number of rain days or intense rainfall days. In contrast with Gaza, seasonal vegetation has a moderate decreasing tendency. Wetter coastal areas have much longer growing seasons (7 months) in contrast with drier interior where growing season can be as short as 2 months.

Like Gaza, El Niño events strongly decrease rainfall throughout the season while La Niña events lead to enhanced rainfall in January to March.

Gaza

In general, the driest province of Mozambique and the one with fewer rain days. The coastal strip is wetter and with more frequent rainfall, in contrast with a drier interior. Inter-annual variability in seasonal rainfall and rain days is very high (highest in the country). The average dry spell length is the longest in the country, together with Inhambane.

Weakly positive trend in seasonal rainfall at province level, mostly from increased rainfall in December and January. Moderate increase in vegetation cover around the peak of the season. Away from coastal areas, growing season length can be very short (down to less than 2 months).

ENSO impacts are very pronounced with El Niño leading to strongly decreased rainfall throughout the season but especially in January to March. La Niña events usually lead to enhanced rainfall in January to March.

Sofala

Rainfall shows transition values to those of northern provinces. Central coastal areas are wetter and have a long growing season in contrast with interior north which looks more like southern Tete. No significant trend in seasonal rainfall or rain days, but vegetation cover has a decreasing tendency.

El Niño reduces January to March rainfall, while La Niña modestly improves rainfall throughout the season with earlier starts of the growing season.

Manica

Similar to Sofala in terms of the broad features of the climate indicators. Central areas much wetter than northern areas of province. Being an interior province, there are no areas of enhanced rainfall, longer growing periods typical of coastal climates. Northern areas with shorter growing season (3mths) than southern areas (6mths). Overall tendency for increasing seasonal rainfall resulting from increases in December-January not compensated by decreases in October-November. El Niño reduces peak season (January to March) rainfall, while La Niña modestly improves rainfall throughout the season leading to earlier starts of the growing season. La Nina seasons have increased vegetation cover in Feb-Apr.

Zambezia

The wettest province in the country, registering the highest average seasonal rainfall (above 2000mm) in the districts of Lugela, Namarroi and Alto Molocue. Very high (highest) number of rain days and also the highest frequency of heavy rain fall days.

However, there is an overall decreasing trend in seasonal rainfall, mainly from reduced rainfall in October and November. Tendency for fewer seasonal rain days comes mainly from February-April and is stronger in coastal and northern areas. Vegetation cover as a result has a decreasing long term tendency more pronounced in the early stages of the season.

El Niño leads to reduced rainfall in January to March, particularly in the southern areas, while La Niña has little impact. Overall ENSO impacts are modest.

Tete

A province with marked contrasting rainfall varying from fairly dry areas in the southern half to fairly wet in the areas bordering Malawi. Moderate increasing trend in seasonal rainfall due to enhanced rainfall in January. Growing period is fairly short for this latitude, mostly within 2 to 3 months, mostly due to very early end of season conditions more similar to Gaza than to wetter regions of this latitude.

El Niño enhances early season rainfall and vegetation cover, but leads also to shorter seasons, while La Niña strongly increases rainfall in January to March, leading to longer growing seasons.

Nampula

Part of the wetter regions of the country with rainfall around the 1500mm mark, and high number of rain days. Overall decreasing trend in seasonal rainfall, arising from reduced rainfall in November-December and fewer rain days particularly in December. Vegetation cover as a result has a decreasing tendency particularly evident in the early stages of the season.

Both El Niño and La Niña have little impact on rainfall patterns in this province but overall El Nino seasons tend to be shorter.

Cabo Delgado

High rainfall province like Nampula with high number of rain days. Weakly decreasing trend in seasonal rainfall, with reduced rainfall in November-December and fewer rain days. Vegetation cover as a result has a decreasing tendency coming mostly in the early stages of the season.

El Niño leads to much enhanced rainfall during October to December, and little to no impact during January to March. Some tendency for shorter El Nino seasons in the south of the province. La Niña has little effect.

Niassa

High rainfall province like Nampula with very high number of rain days and shortest average dry spell length. No noticeable trend in overall seasonal rainfall, but reduced rainfall in November-December and fewer rain days. Vegetation cover as a result has a decreasing tendency in the early stages of the season.

Like Cabo Delgado, El Niño leads to much enhanced rainfall during October to December, and little to no impact during January to March. La Niña has also little effect.

RAINFALL

Average Seasonal Rainfall

The rainfall season lasts from October to May, though most rainfall is concentrated within November to April (see chart below). Fig 1 shows the mean seasonal precipitation in the 1982-2017 period.

Areas of lower rainfall include the southern provinces of Maputo, Gaza and Inhambane as well as the southern half of Tete. In western Gaza rainfall is lowest, with seasonal amounts of around 500mm.

High rainfall areas include the four northern provinces of Cabo Delgado, Niassa, Nampula and Zambezia. In the latter, seasonal amounts may reach just over 2000mm

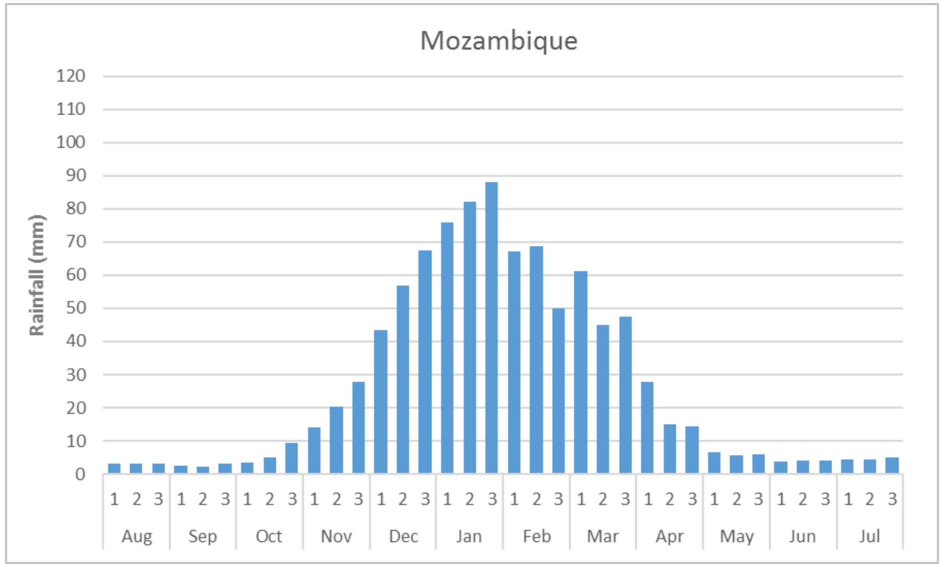
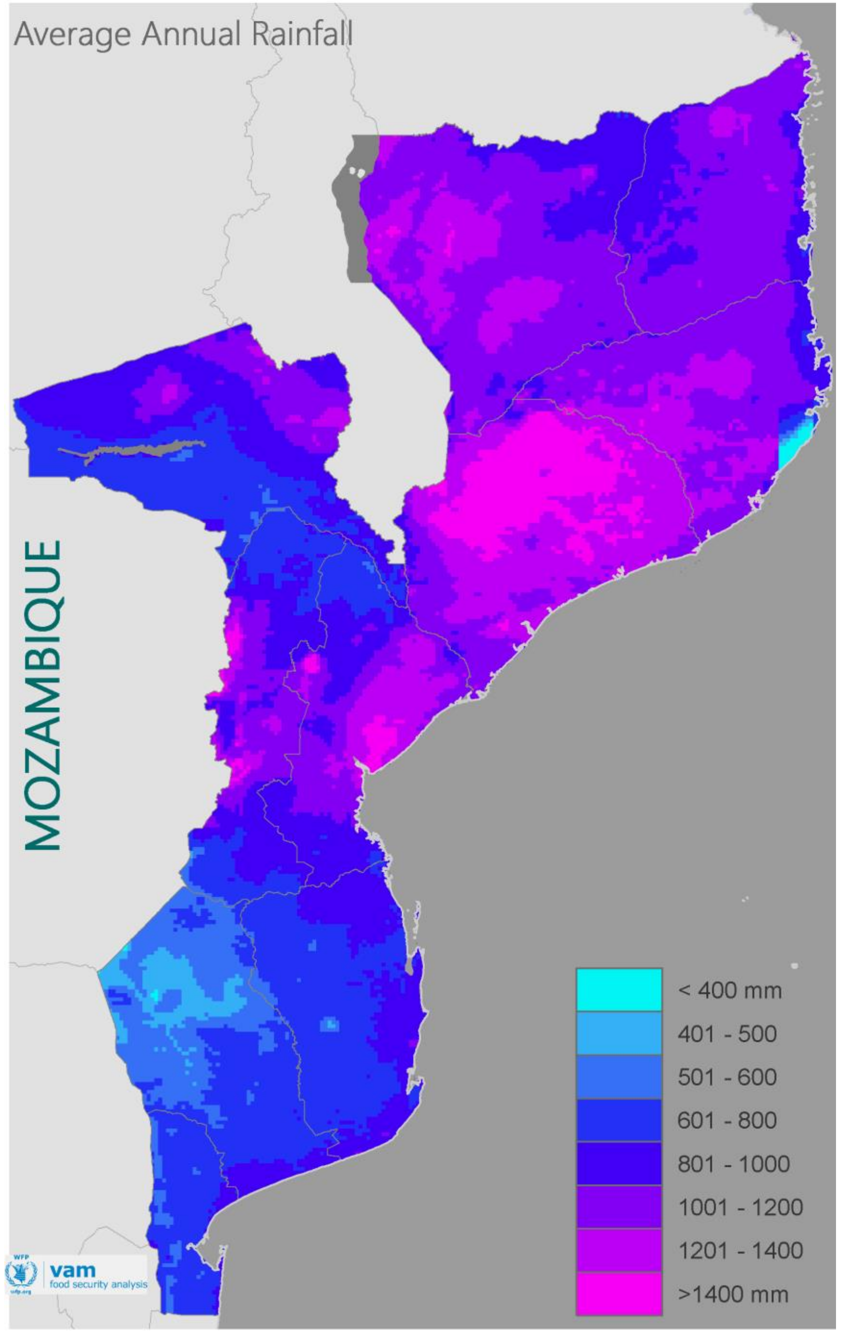
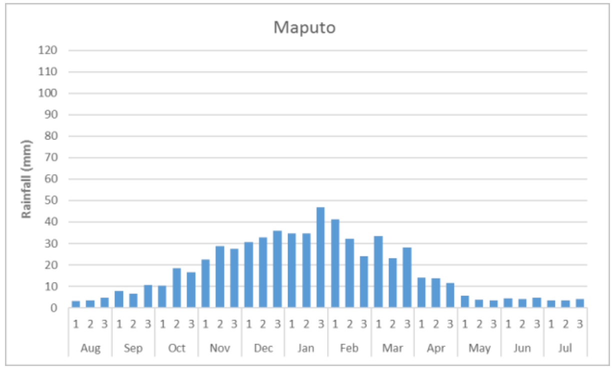
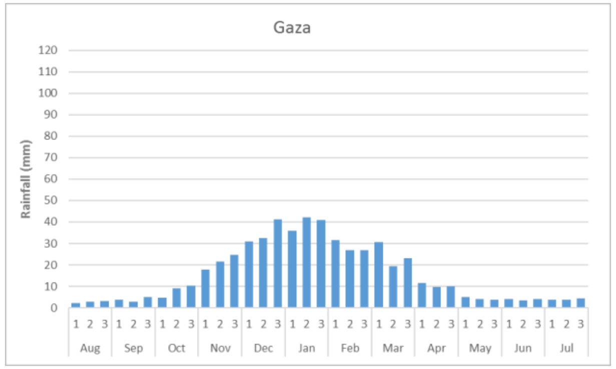
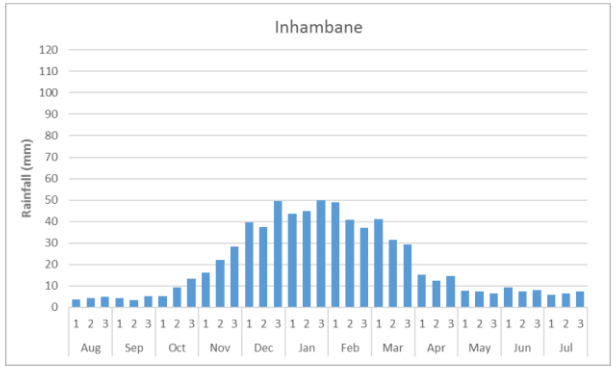


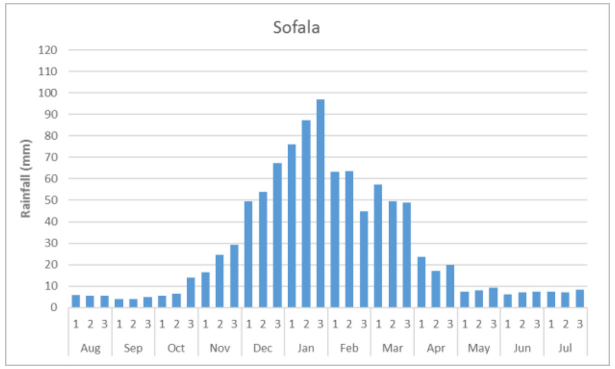
Fig.1 – Average annual rainfall

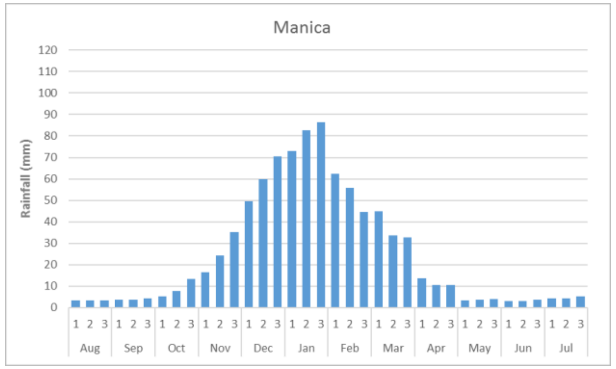


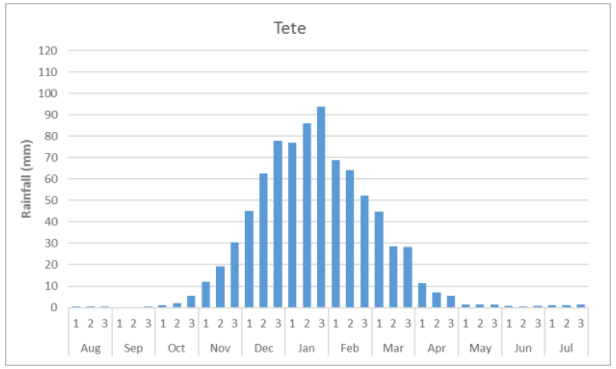


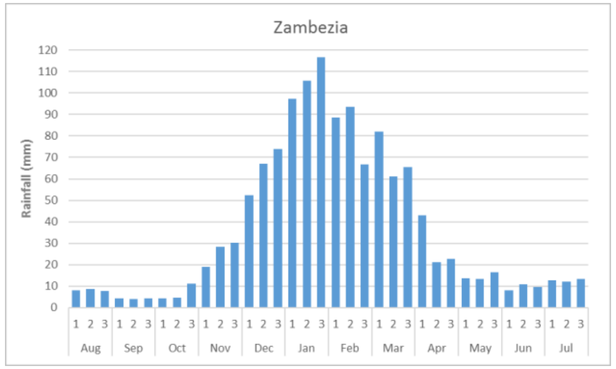


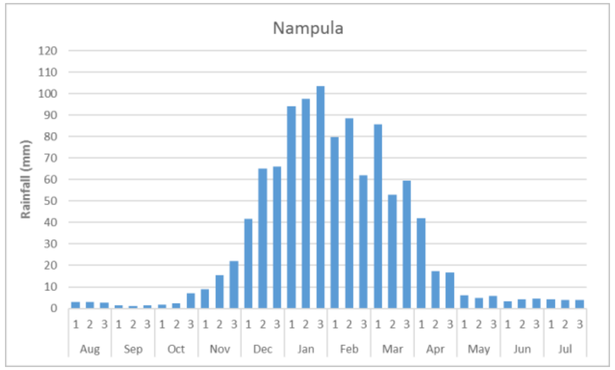


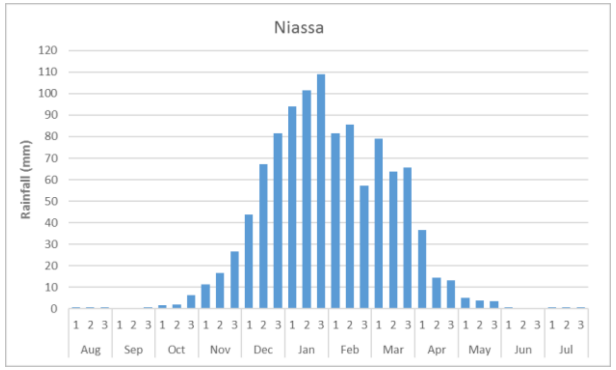


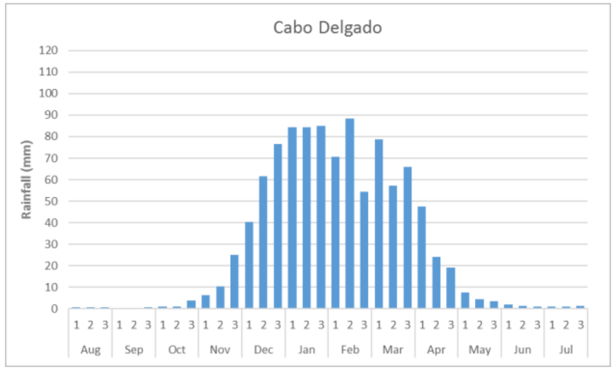












Rainfall: Province-level long term average seasonal profiles

The charts show the long term (1982-2016) seasonal rainfall profile for each of the provinces of Mozambique. Apart from sizeable variations in amount, the rainfall regime across the country is clearly unimodal. In northern and interior provinces rainfall is limited to the October-May period, but in coastal provinces, significant rainfall can still occur until August.

Charts: Blue bars represent long term average of 10 day mean provincial rainfall.

Rainfall: a broad long term view

Fig 2 shows a plot of the all-Mozambique seasonal rainfall from 1982-83 to 2016-17. It ignores within country variation in order to provide a rapid overview of the changes in rainfall along the available temporal record.

The plot illustrates how rainfall variability occurs at several scales: there are medium term variations such as the dry period of the early 90s followed by a very wet period from the late 90s up to 2000, after which seasonal rainfall has been aligned with the long term average. These patterns are better perceived by the 10 year moving average shown as a red line in the plot.

Super-imposed on these medium term changes, there are substantial year on year variations with sometimes drastic changes in rainfall from one year to the next.

Overall, at this scale there is no noticeable trend in the seasonal rainfall. Trends are very slow long term variations and for Mozambique at country scale, any slow change is swamped by the magnitude of both medium term changes and the year on year variations.

However, there is a need to examine whether there may be sub-national trends within this country sized window (next).

Fig.2 – All-Mozambique seasonal rainfall amounts

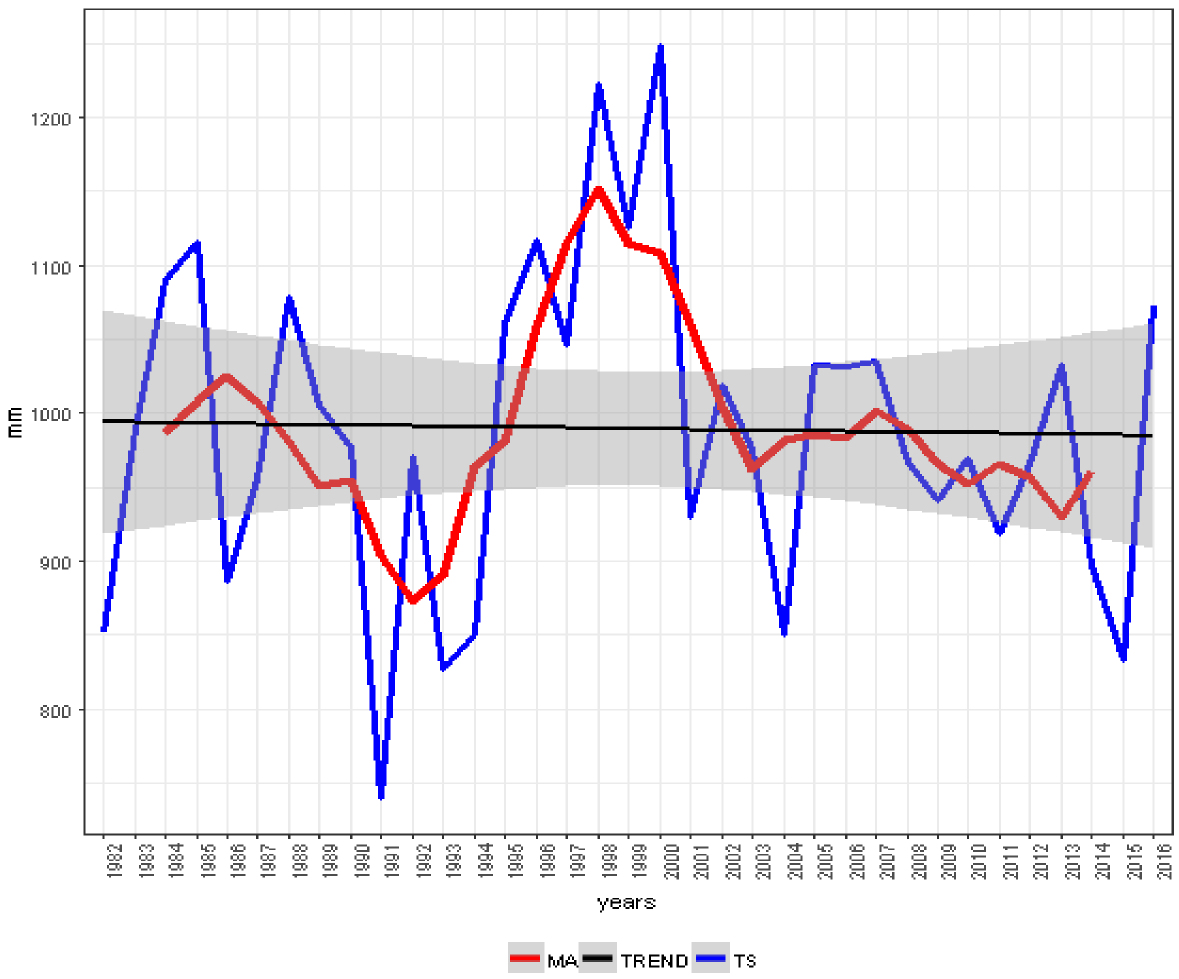
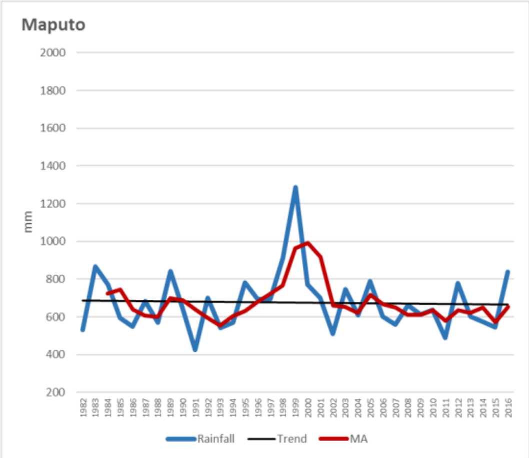
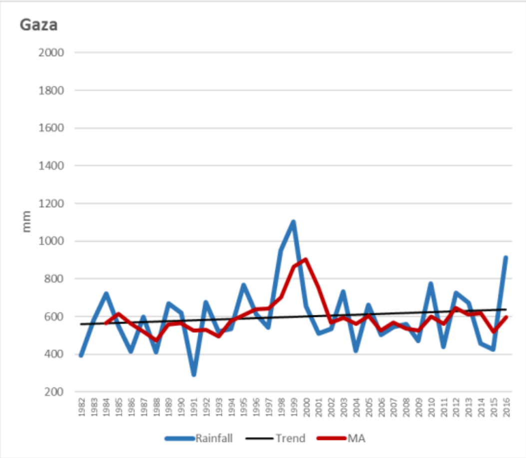
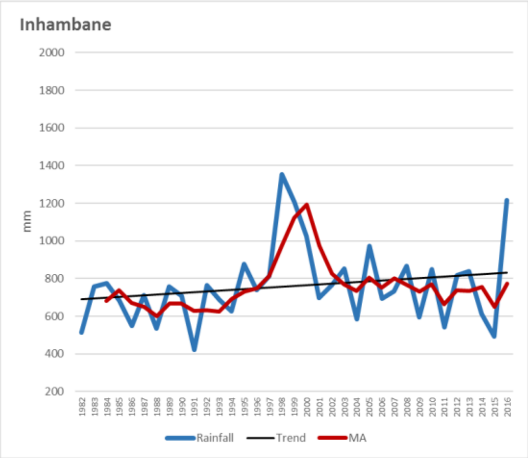
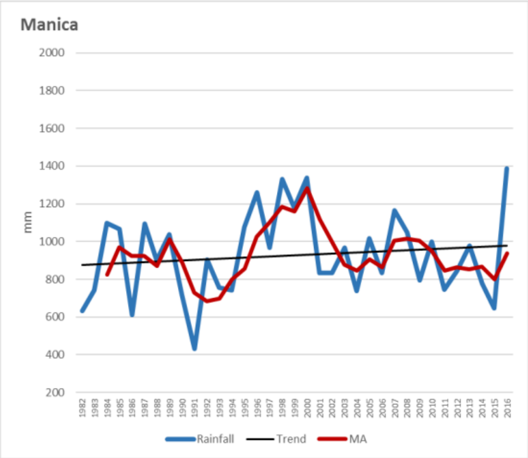


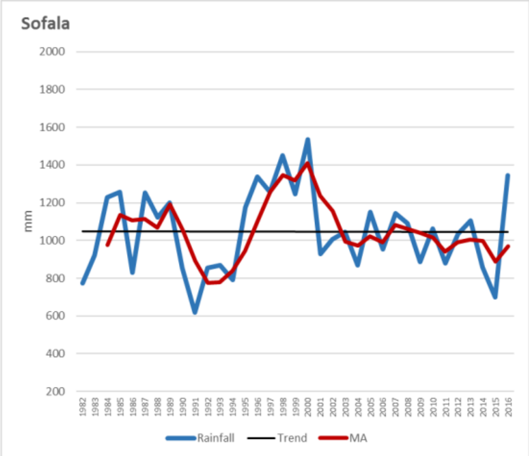
Chart: In blue (TS) the seasonal rainfall amounts. In red (MA) a 5 year moving average. In black (Trend) is a fitted OLS trend line. The moving average line smooths sharp variations and highlights broader patterns of variation.

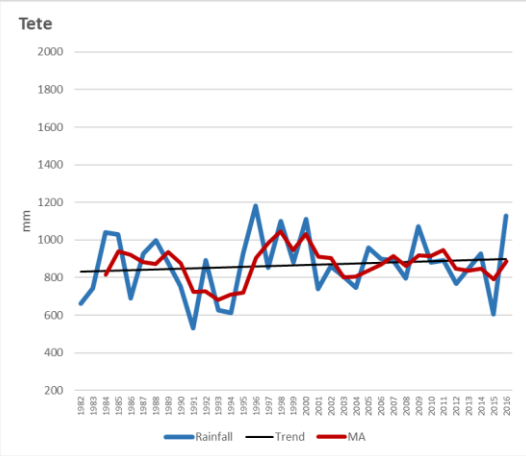


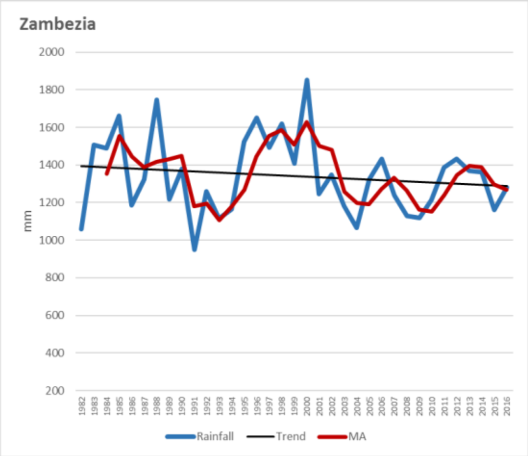


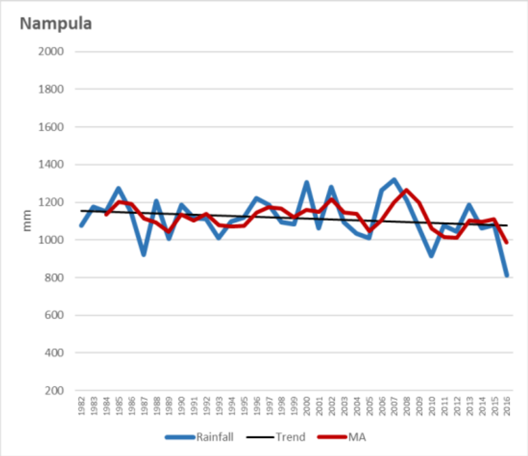


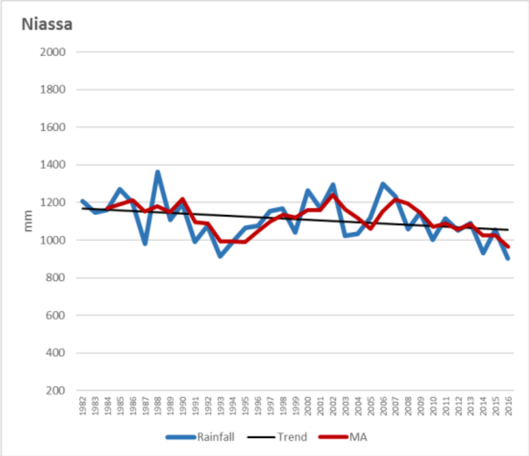


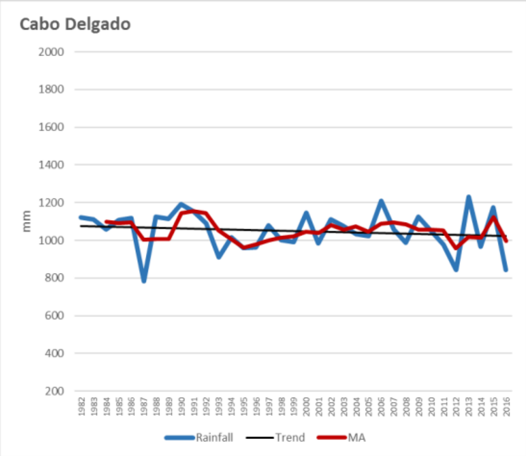












Charts:

Blue lines show province average seasonal rainfall amounts.

Red line is a 3 year moving average to highlight broad temporal patterns.

Black is a fitted trend line.

Rainfall: Long term view by province

These charts display the province average seasonal rainfall from 1982 to 2016. Some relevant features emerge:

- In the three northernmost provinces, rainfall is less variable (year on year) than elsewhere; it also displays a tendency for decreasing seasonal rainfall, which is also evident in Zambezia.
- Southern and central provinces show either no discernible tendency or a tendency for increasing seasonal rainfall and display much higher inter-annual variability.
- The sequence of dry- wet-average period highlighted in the national chart (Fig.3) can be seen in all provinces except the three northern ones.

Rainfall inter-annual variability

Inter-annual variability quantifies how much seasonal rainfall varies from one season to the next. It is expressed as a map of the coefficient of variation of the annual rainfall in the 1982-2017 period.

Rainfall inter-annual variability is higher in areas of lower seasonal rainfall totals, i.e. drier areas are also more variable year on year. This is clear from Fig 3 and Fig 1: the most variable areas are Inhambane, Maputo and Gaza (particularly the drier western areas).

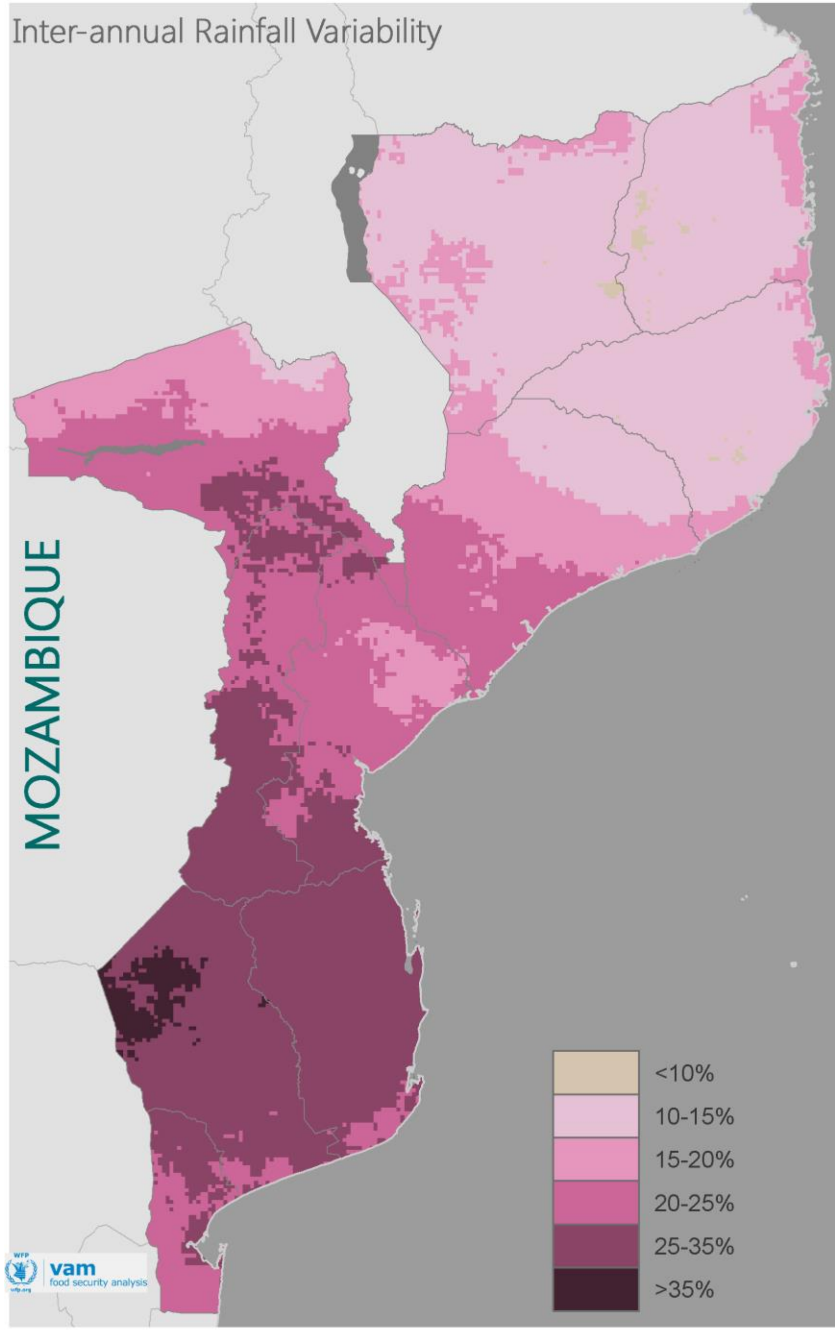
Inter-annual variability is a climate factor of major importance as it limits livelihood options: high rainfall variability contributes to the adoption of conservative, risk-averse strategies, and a progressive shift to non-agricultural livelihoods (pastoral, mining). Beyond a certain threshold agricultural livelihoods cease to be feasible.

Note that inter-annual variability includes two components – short term year on year random variations and a longer term temporal trend.

In Mozambique the first component has overwhelming dominance (Fig 3). Zones with higher inter-annual variability largely correspond to the ones with higher food insecurity risk.

CV, Coefficient of Variation: CV is defined as the ratio of the standard deviation (SD) of a time series by its average. The SD expresses the variability and the division by the average, standardizes it allowing comparisons between locations with widely varying averages (e.g. wetter vs drier zones)

Fig.3 – Inter-annual rainfall variability (CV) 1981-2016



Annual rainfall trends

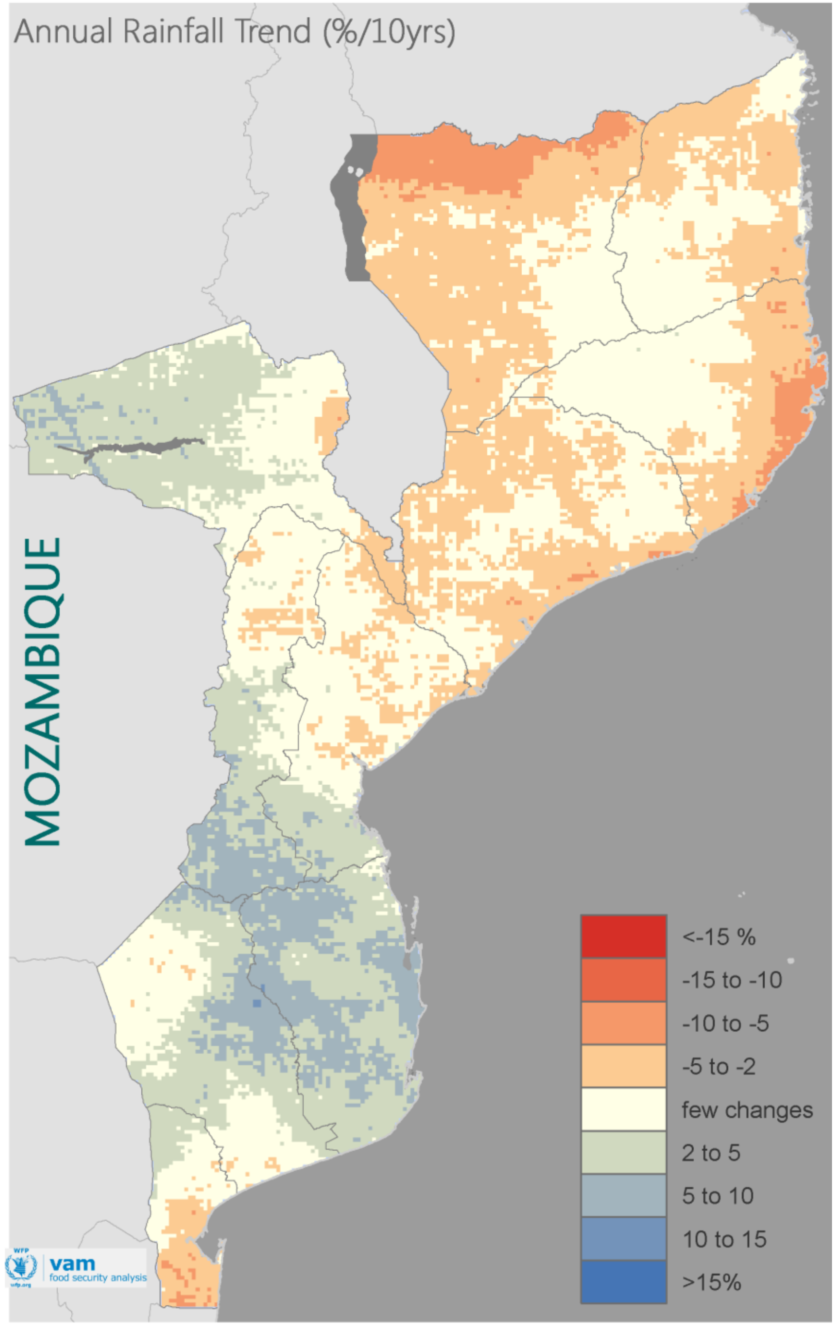
As shown in Fig.3, there is little to no long term trend in seasonal rainfall at the whole country level.

Fig 4 shows the long term trend in seasonal rainfall calculated on a pixel by pixel basis. Some patterns emerge – the southern and western zones show a positive trend while the central and northern have mostly negative trends. Most of these long term trends are moderate, except for some areas of Niassa province bordering Tanzania and some coastal areas of Nampula province.

This analysis can be broken down further by mapping rainfall trends for each month separately. This allows us to understand how long term rainfall changes are distributed along the season: e.g. you could have a long term decrease in the first half of the season and an increase in the second half, balancing out into no apparent trend over the whole season.

This is presented in the next section.

Fig.4 – Annual rainfall trend (%/10yrs)



Trends: Trends quantify long term tendencies in a given variable such as rainfall. Negative trends indicate that the variable (seasonal rainfall in this case) tends to decrease over the length of the analysed record. For positive trends the reverse happens.

For rainfall, trends are expressed in mm/year (mm of rainfall increased or decreased per year). However, we chose to express the trend in terms of variation every 10 years (which we think is easier to grasp); we have further normalized the rainfall variation by the long term average, so that the magnitude of the variation can be better understood.

Example: A trend of -2.4mm/year for a location with an average seasonal rainfall of 1200mm (Nampula), is here expressed as -2%/10years. The same trend for a location with 600mm average seasonal rainfall (Gaza) is expressed here as -4%/10years, highlighting the fact that in Gaza the same trend leads to proportionally higher reduction in rainfall.

Monthly rainfall trends

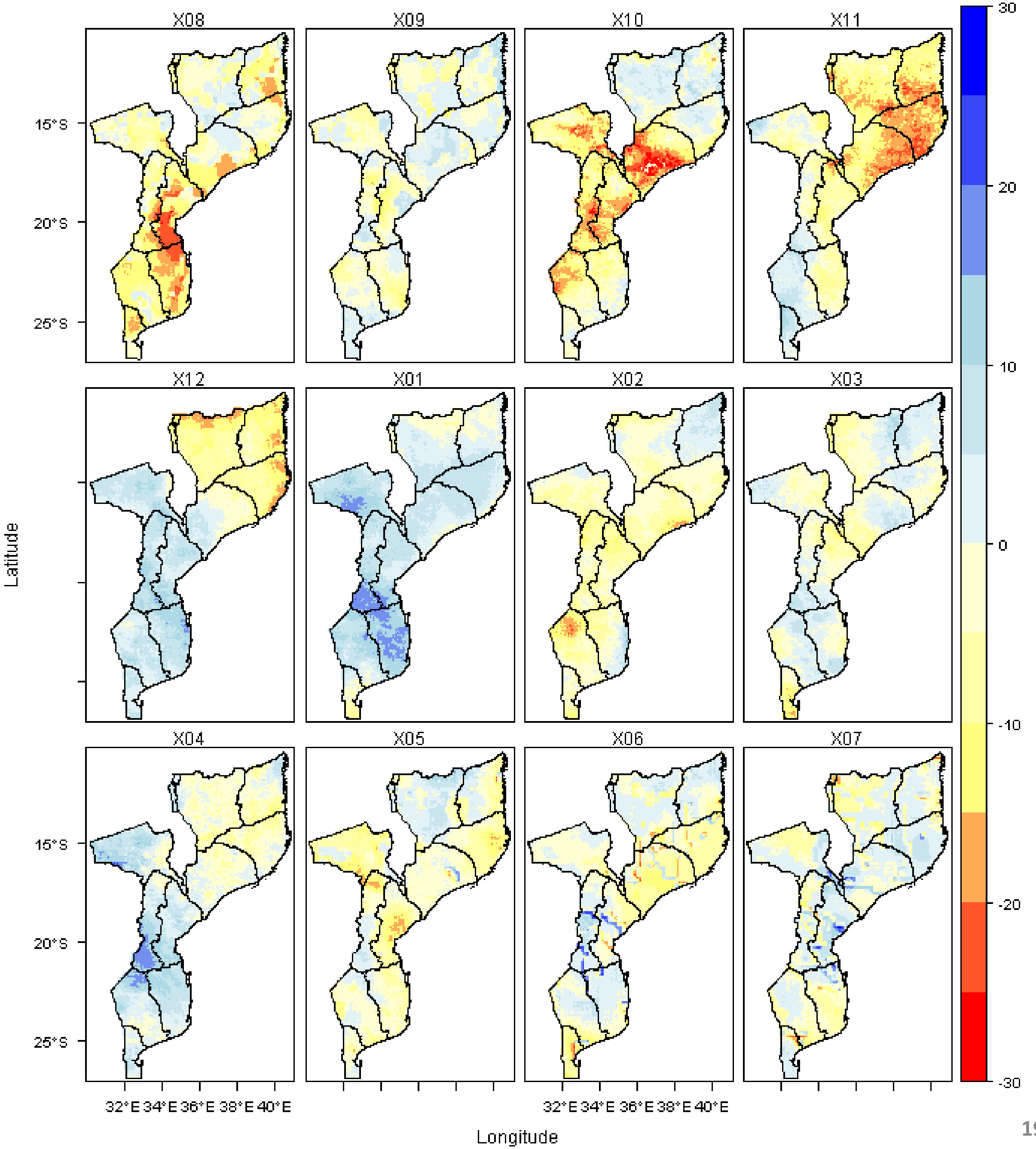
The monthly trend analysis is presented in Figure 5: each panel shows the trend in monthly rainfall for each month in the calendar year.

The maps reveal a negative trend in rainfall in central and northern Mozambique during October and November (and partly December). This may be reflected in a tendency for later onset of the growing season due to more frequent low rainfall in the very early stages of the season.

In December and January trends are generally positive, particularly in the southern half of the country. January is already the wettest period in the country and seems to be getting increasingly wetter.

The second half of the season (February and March) are less well defined – some drying tendency in southern Mozambique for February may be relevant. From April onwards, rainfall amounts are fairly small and trends becomes less relevant.

Fig.5 – Rainfall monthly trends



Monthly rainfall trends

This section summarizes the monthly trend analysis into a joint map and plot (Fig 6a and 6b). The analysis identifies regions where the monthly trends behave in a similar way.

Three main regions were identified and shown in the map. The aggregated monthly trends for each zone are plotted in the chart.

Zone 2 (in orange) shows strong negative rainfall trends in October and November with slightly positive trends in December and January and moderately negative in the rest of the season. Zone 3 (blue, north of the country) has similar behaviour but the strong negative trends are in November and December, with no significant trends in the rest of the season. Zone 4 (green, south and west) shows early season decreasing trends but mainly increasing rainfall trends in December and January.

The monthly trends confirm the overall trends shown in Fig 4, but add useful sub-seasonal detail. The decreasing seasonal rainfall in the north of the country (zones 2 and 3) mainly results from significant decreases in rainfall during the early stages in the season. This will be confirmed later when looking at trends in the timings of the season.

The increasing seasonal rainfall in the south and western regions arise mostly from increases in the wetter period of the season, with moderate tendencies for increasingly drier early season stages.

Fig.6a – Rainfall monthly trend zoning

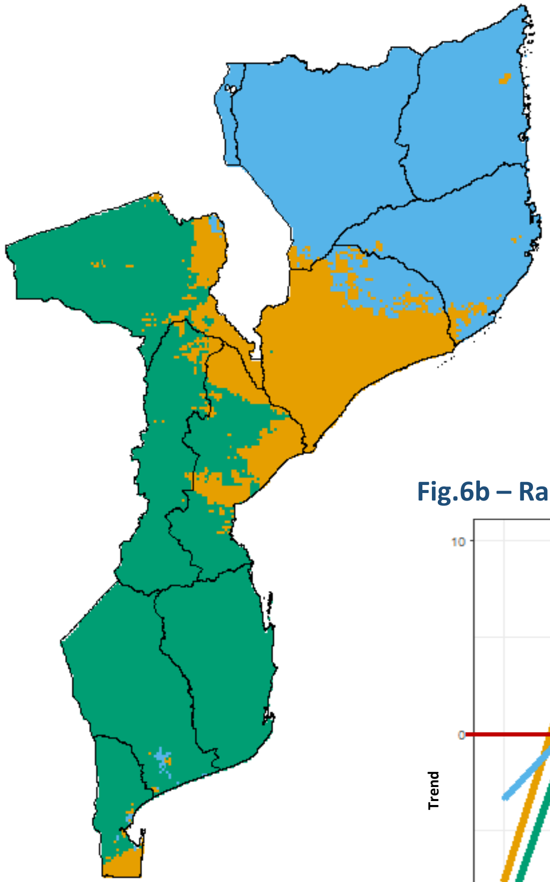
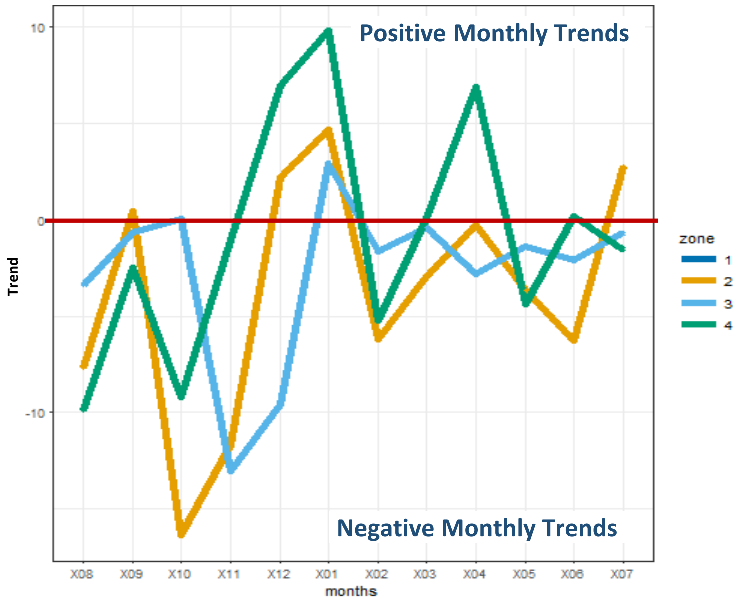


Fig.6b – Rainfall zonal monthly trend temporal evolution



RAIN DAYS

Fig.7 – Average number of rain days per season

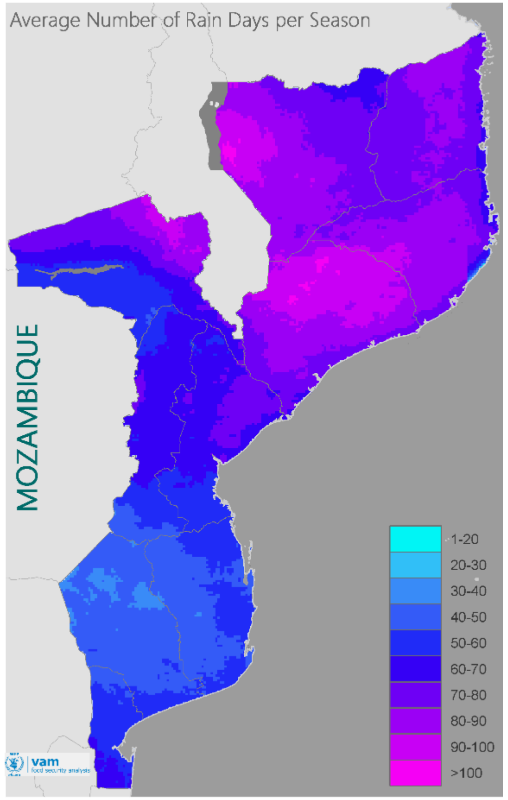


Fig.8 – Inter-annual variability in number of rain days

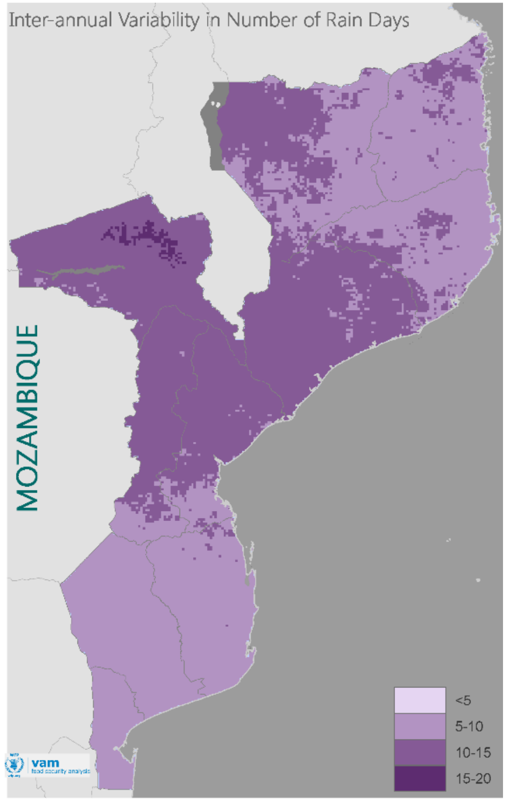
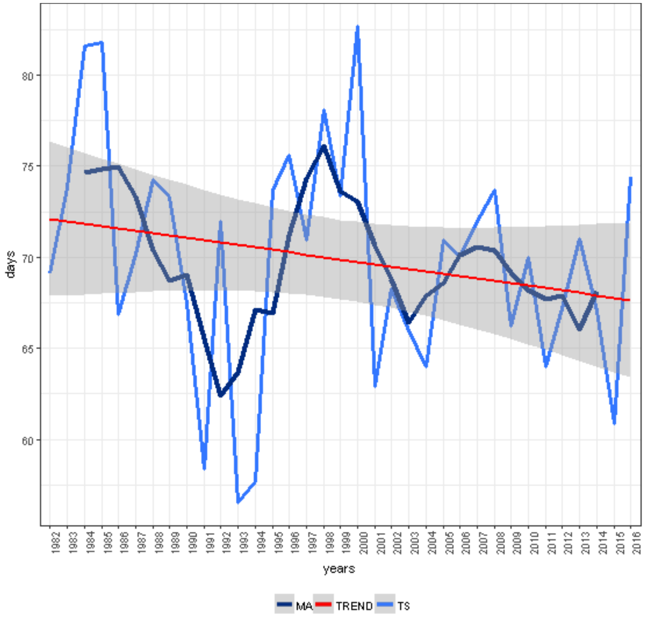


Fig.9 – All-Mozambique seasonal number of raindays



Rain days: Average and Variability

The average number of rain days (above 1mm) has a spatial pattern broadly similar to that of the seasonal rainfall as would be expected.

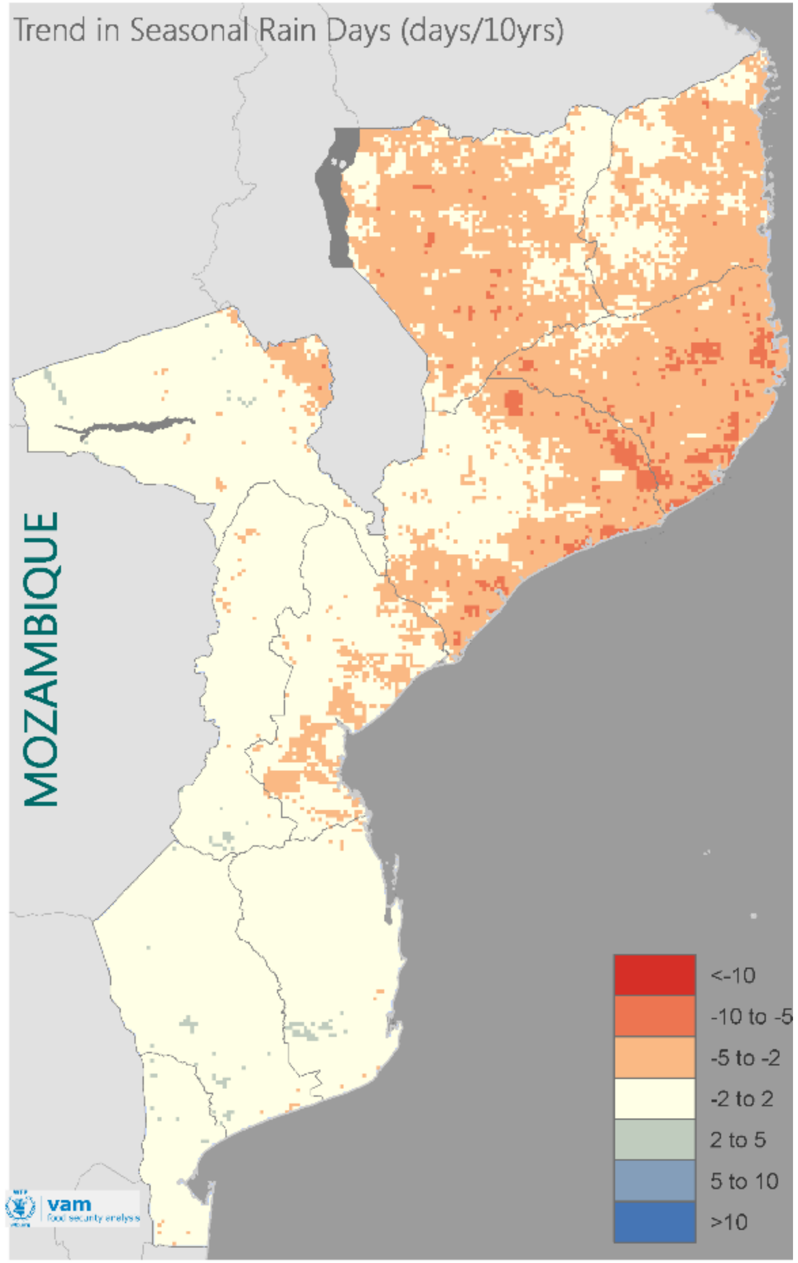
Areas with greater number of rain days are in the provinces of Zambezia and Niassa as well as in areas of Tete neighbouring Malawi. Here, the seasonal number of raindays reaches 100, for a season length of 130 to 140 days.

Lowest frequency of rainfall occurrence is seen in Gaza and western Inhambane provinces matching areas of low seasonal rainfall where the number of rain days is mostly between 30 to 50, in spite of a fairly long rainfall season. This immediately signals this as a region with significant likelihood of dry spells.

Inter-annual variability in the number of rain days is higher in Tete province and along the southern and central zones. However, in the area where seasonal rainfall is more variable (western Gaza), the number of rain days has relatively low variability.

Long term patterns in rain days for Mozambique are similar to those of seasonal rainfall but show more of a decreasing long term trend. This is analyzed more in detail in the next section.

Fig.10 – Trend in seasonal rain days (days/10yrs)



Rain days: Trends

The trend in seasonal number of rain days shows negative values in the four northern provinces with up to 6 fewer rain days every 10 years.

The southern and western provinces show a moderate positive tendency of no more than 2 rain days per 10 years.

Rain days: Monthly Trends

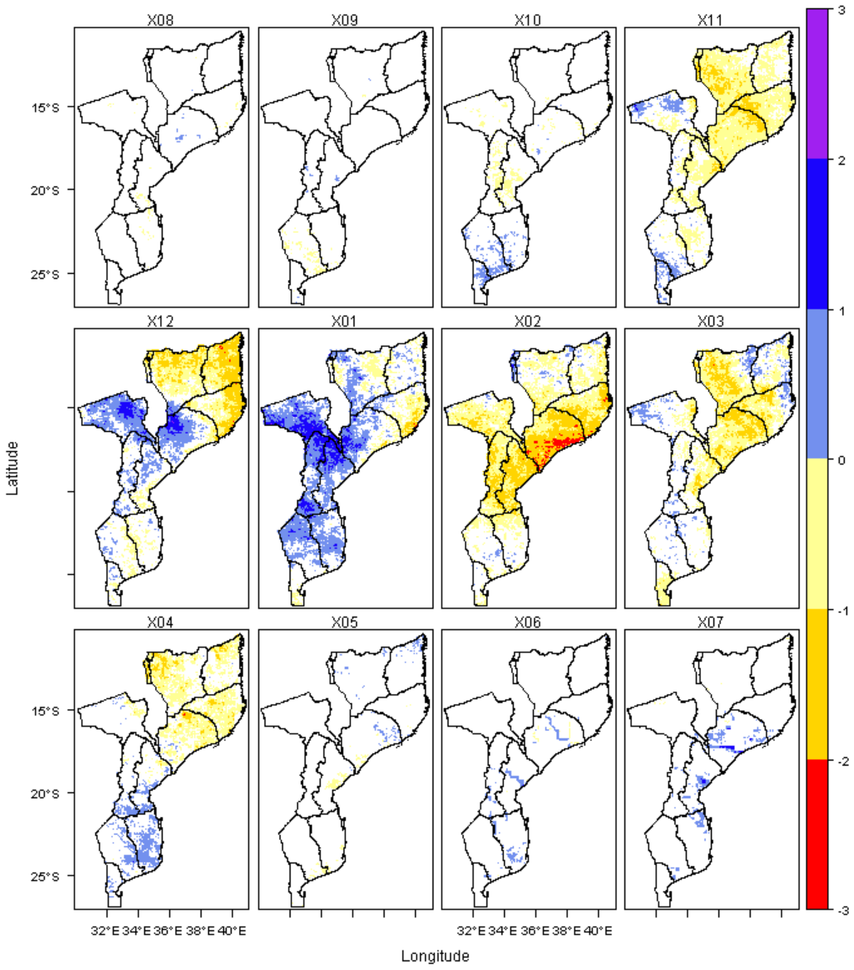
Analysing the trend on a monthly basis (Fig 11), shows that in the northern provinces the tendency for fewer rain days is present in most months, except January.

In the southern provinces (Maputo, Gaza, Inhambane) except for an increase in January there is no defined tendency in the number of rain days.

In December and particularly January there is a more marked tendency for an increase in rain days. This is reversed in February with a marked tendency for a decrease in the number of rain days particularly in Zambezia, with some continuation in March.

There is good agreement with the rainfall trends as expected, but negative tendencies in the number of rain days will also lead to an increase in the length or frequency of dry spells.

Fig.11 – Monthly rainy days trend (days/10yrs)



Monthly Rain days trends

The rain days monthly trend analysis can be summarized into a joint map and plot (Fig 12a and 12b). The analysis identifies regions where the monthly trends behave in a similar way.

Four main regions were identified and shown in the map. The aggregated monthly trends for each zone are plotted in the chart.

Zone 5 (light green) is an area with decreasing number of rain days throughout the season but in particular in December. Zone 2 (orange) also shows a decrease through the season but more pronounced in November and March. Zone 4 (green) shows moderate increase in December and January but strong decreases in February and March. Zone 1 (dark blue) apart from a moderate increase in January shows only small fluctuations through the season.

Fig.12a – Rain days monthly trend zoning

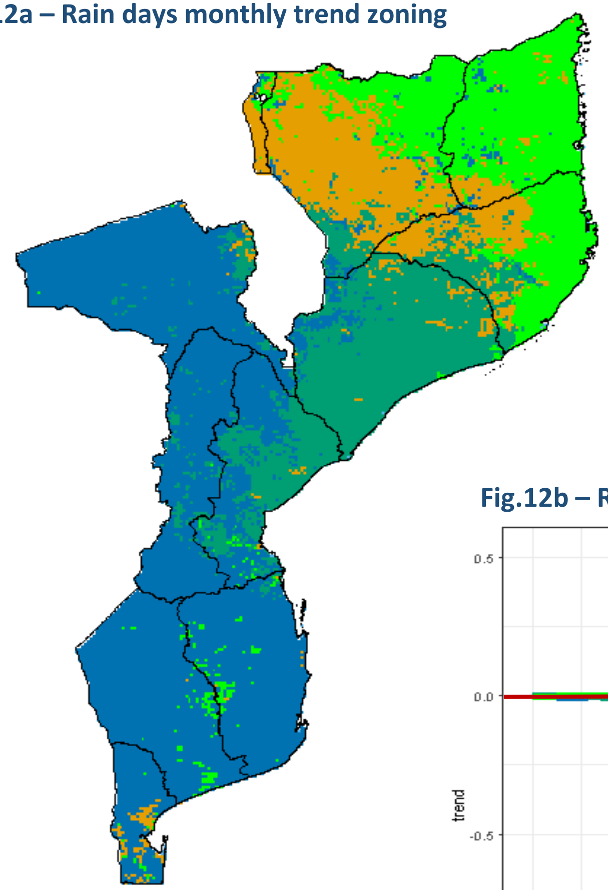
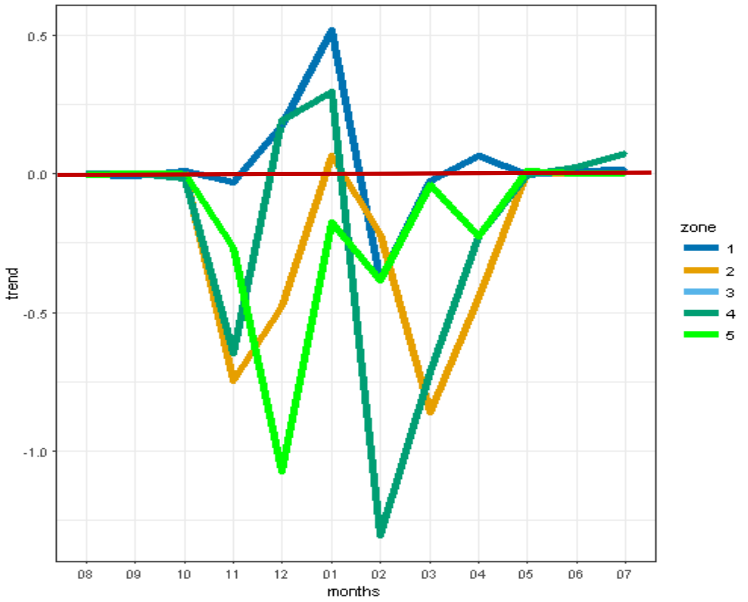


Fig.12b – Rain days zonal monthly trend seasonal evolution



HEAVY RAINFALL

Very heavy rains are defined as days with more than 20mm of rainfall

[Ref. ETCCDI Climate Extremes Indices].

For each season on record, the total number of these events are produced and analysed. The analysis does not look into continuous sequences of these types of events

Fig.13 – Annual very heavy rain days mean

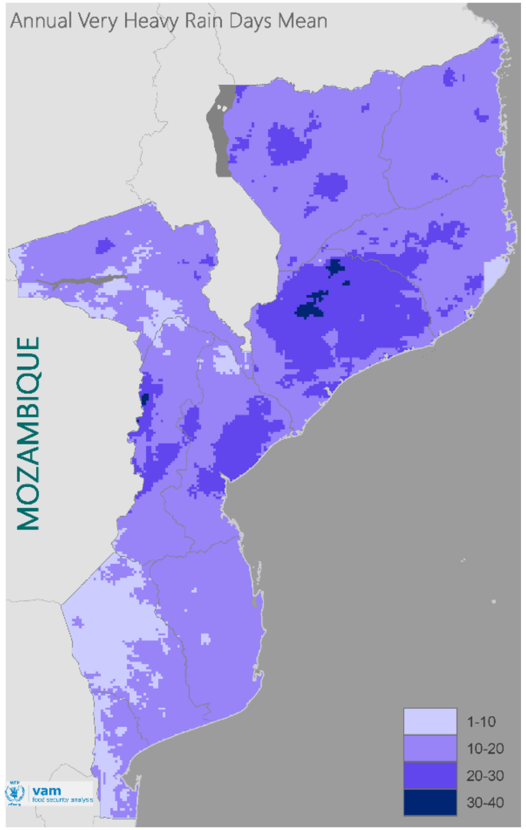


Fig.14 – Annual very heavy rain days trend (%days/10yrs)

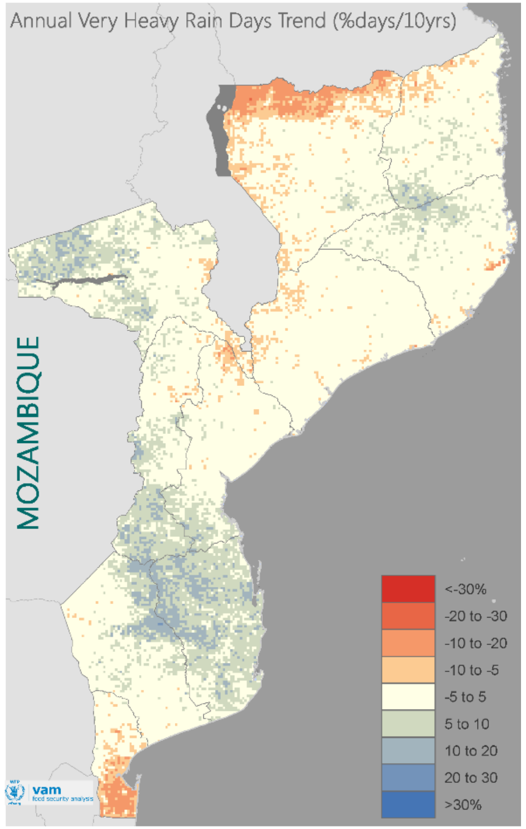
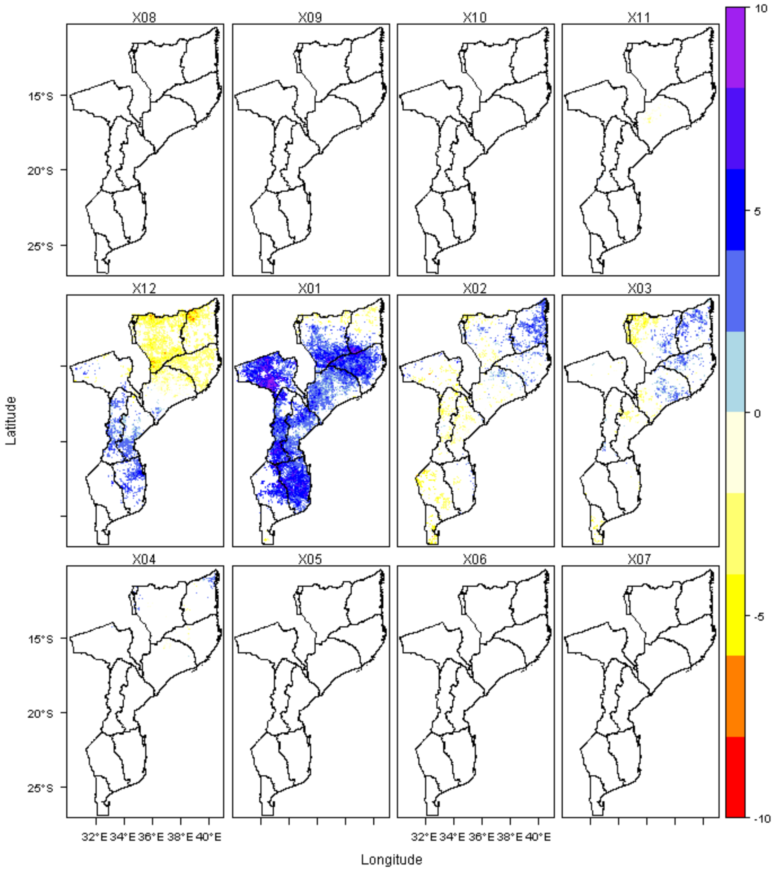


Fig.15 –Heavy rain days monthly trend (days/10yrs)



Very Heavy Rain Days: Average

The pattern of frequency of very heavy rainfall days (Fig 13) is fairly similar to the patterns in the average seasonal rainfall (more/fewer heavy rain days are expected where seasonal rainfall is higher/lower):

Zambezia province is where heavy rain days are more predominant (between 30-40 per season) with pockets in Sofala province.

Lowest frequency is in western Gaza province where on average fewer than 10 are registered per season.

Very Heavy Rain Days: Trends

The trend in heavy rainfall days (Fig 14) is similar to that of seasonal rainfall as well. In the south and west of the country an increase in the number of very heavy rainfall days is noticeable matching the tendency for increased seasonal rainfall.

In the north the tendency is for a decrease along the border with Tanzania and Malawi and very moderate increases elsewhere. Note that (Fig 15) the increase in heavy rain days is mostly concentrated in January (and some from March and April in the north), with December making a smaller contribution.

DRY SPELLS

Dry Spells are defined as continuous periods with rainfall less than 2mm. Amounts smaller than 2mm are considered not to impart benefit to vegetation or crops.

[Ref. De Groen and Savenije (2006)]

For the analysis we looked into the longest dry spell within the core seasonal period of December to March. Hence one value is obtained per season, which is then analyzed in the usual way.

Dry spells: Average / Variability

Seasonal rainfall amounts are not sufficient to evaluate the quality of the growing season; distribution of rainfall is equally important, in particular the presence of dry periods that maybe long enough to overcome crop's natural resistance.

This section looks at dry spell occurrence within the core seasonal period of December to February (DJF). Dry spell is defined as the number of days with rainfall below 2mm (amount judged too low to be of agricultural significance).

For each season the longest dry spell within the DJF period is derived and the average over all seasons on record is produced. The result is shown in Fig 16: the area with the longest dry spells (20-25 days) is in Gaza and Inhambane provinces. The shortest average dry spells occur in the northern provinces away from the coast, with lengths of 5-10 days.

Regions with fairly long average dry spells also show very large inter-annual variability (Fig 17) in dry spell length (6 to 8 days).

Fig.16 – Average longest dry spell in DJF

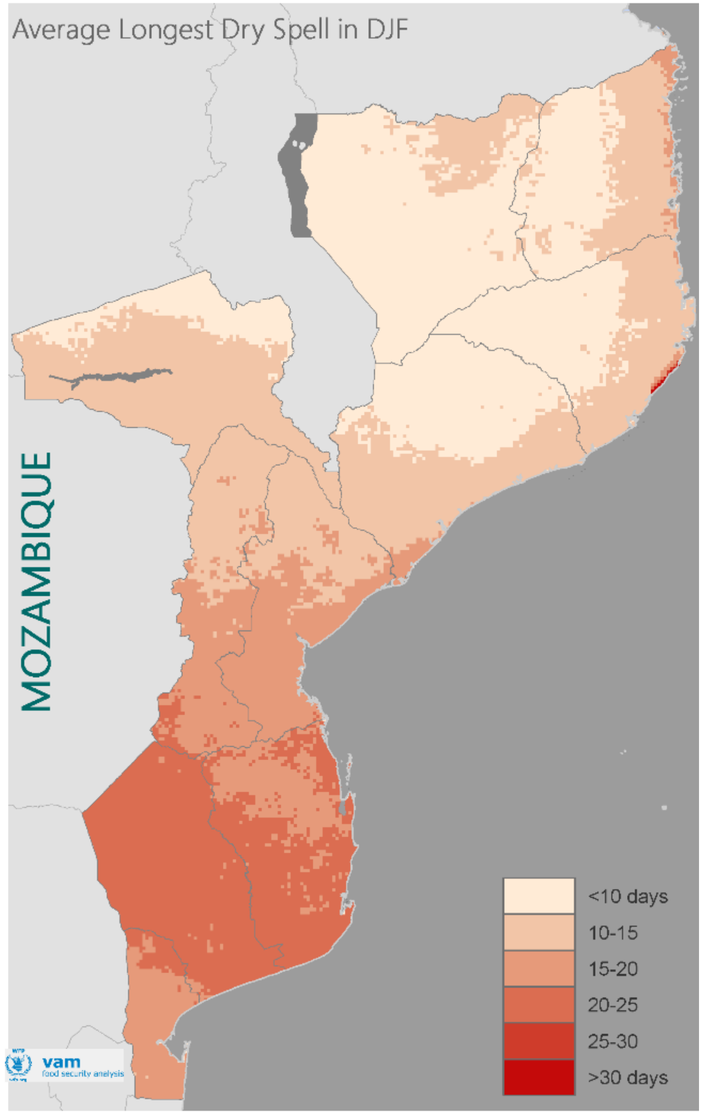


Fig.17 – Inter-annual variability in dry spell length

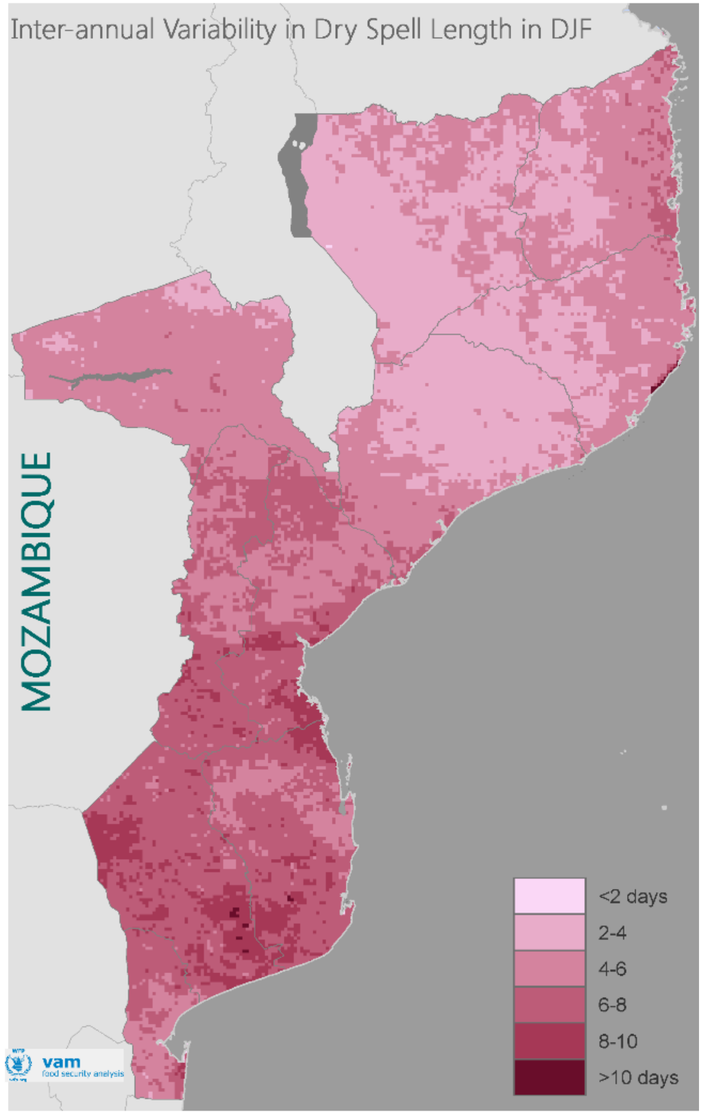
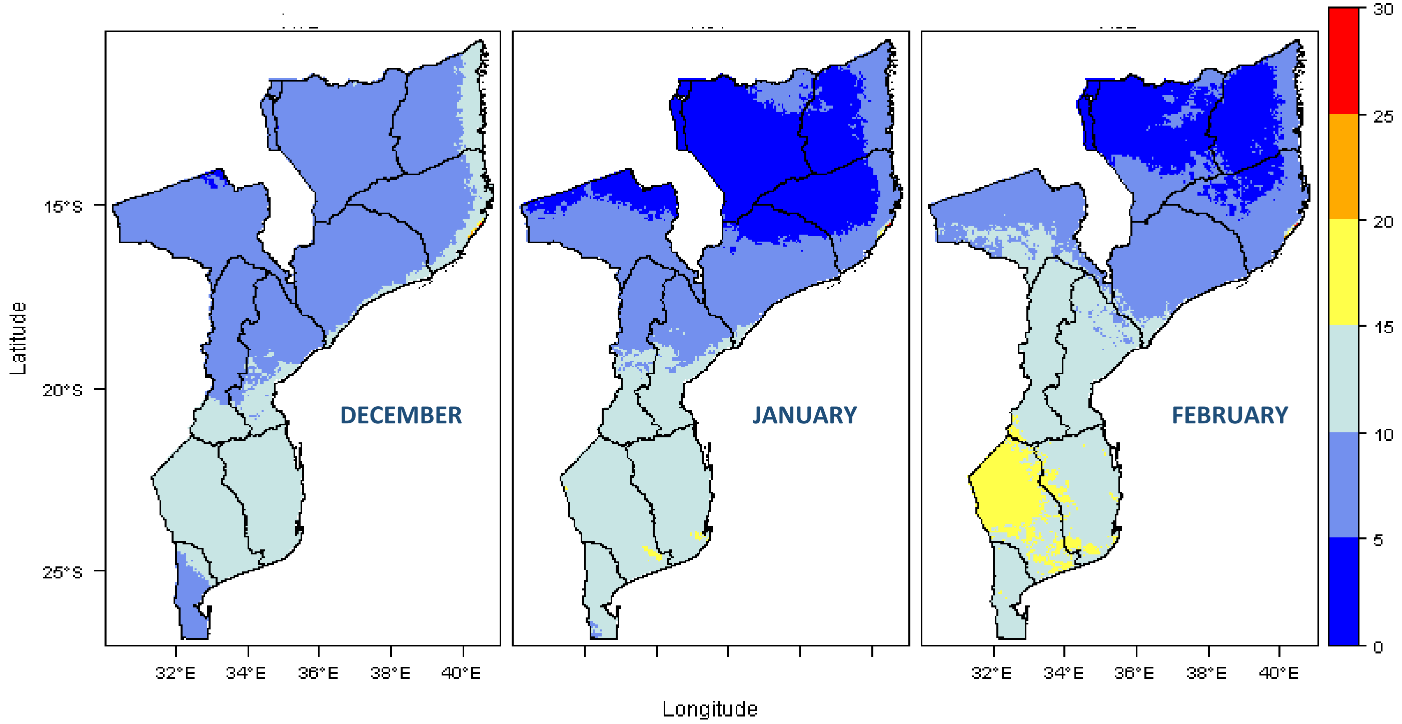


Fig.18 – Average maximum dry spell in December, January and February



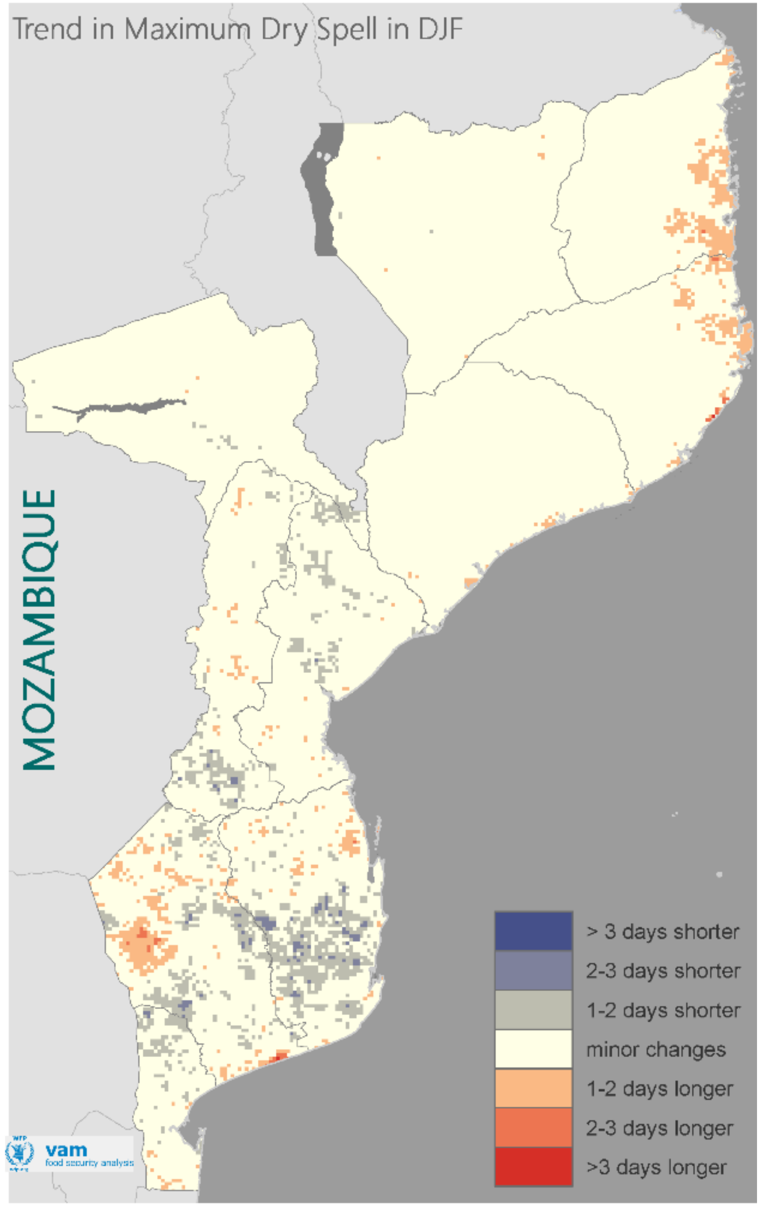
Dry spells: Monthly Averages and Trends

The calculations were also done on a monthly basis since the DJF longest dry spell could be influenced by events of early end or late onset of season (Fig 18).

For the two core months of the season (December and January) in the southern half of the country, the average longest dry spell is of 10-15 days, in contrast with 5-10 days in the northern half, down to shorter than 5 days in the northernmost areas of the country. In February, average longest dry spell length increases in Gaza province to 15-20 days.

Dry spell lengths show a moderate tendency to decrease in the southern and central provinces, except in parts of western Gaza, where the reverse tendency is observed. In the north of the country the tendency is very week, except for a trend of increasing dry spells along the coast.

Fig.19 – Trend in maximum dry spell in DJF



GROWING SEASON TIMING

Growing Season timings represent the dates of onset and end of suitable and sufficient moisture conditions to enable the growth of crops and natural vegetation; the length of the growing season is defined from the difference between these two dates.

Moisture conditions are derived through the use of a simplified water balance model, that accounts for the rainfall available at every time step and estimates how much is evapotranspired and how much is stored in the soil. At each time step the available water for crops and vegetation is derived as the current precipitation plus the water left in the soil in the previous time step.

The growing season is assumed to start (end) when the available water exceeds (drops below) 35% of the potential evapotranspiration according to the classic procedures used by FAO in analysis of crop water requirements (e.g. WRSI model)

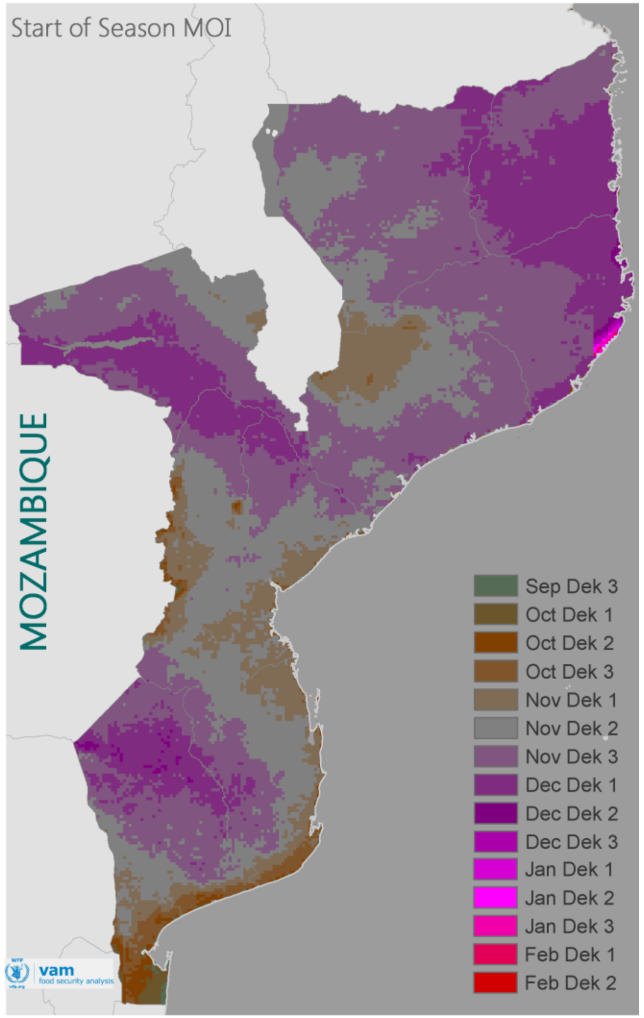


Fig.20a – Average start date growing season

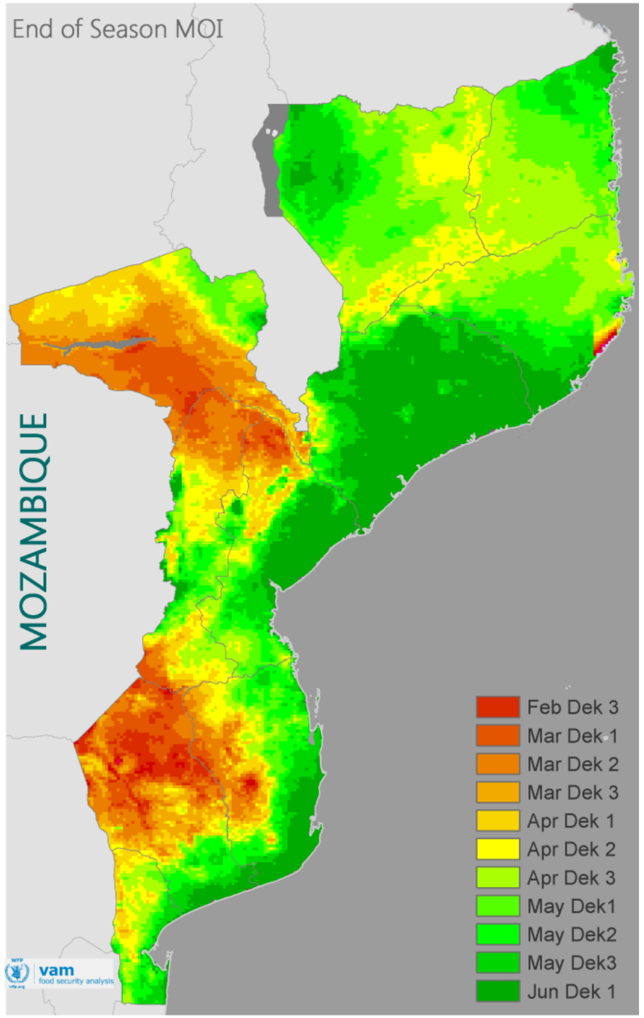


Fig.20b – Average end date growing season

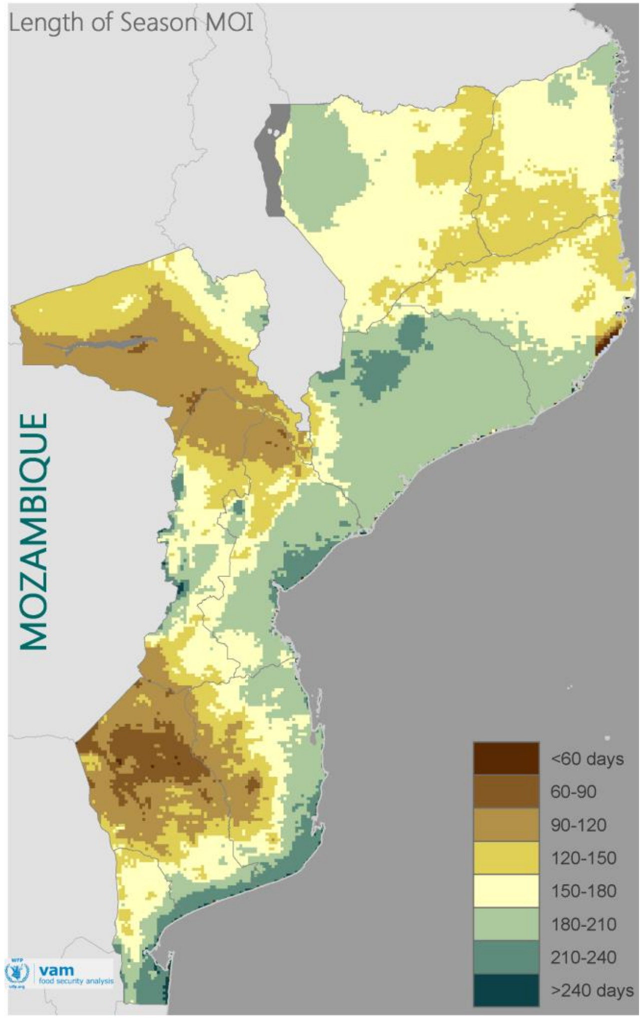


Fig.20c – Average length growing season

Growing Season: Start, End, Length

The start of the rainfall season (Fig.20a) has a clear south to north gradient, with earlier starts (mid October) in the southernmost areas of the country and occurring progressively later towards the north of the country (late November).

The end of the season (Fig.20b) is somewhat less variable – in northern areas the end is mostly in early April with some areas near Tanzania ending in late April. In southern and western areas the seasons ends in late March or even in early march in some spots in Tete, Sofala and Manica.

The resulting length of season map shows Gaza and Tete provinces to have the shortest lengths of growing season, mostly below 3 months and as short as 2 months. Note that the rainfall season is longer than this – growing season here refers to a period of consistent and significant moisture levels.

In most of the rest of the country, growing season lengths vary between 5 to 7 months.

Growing Season Length: Variability, Trend

As expected for fairly dry areas, the length of the growing season (LGS) is far more variable in Gaza and parts of Inhambane than elsewhere (Fig 21). Although Tete province also has short LGS, it is much less variable from year to year, as the rainfall season is less spread out – more intense and regular rainfall leads to more regular growing seasons. In Gaza, a longer season of irregular rainfall, leads to growing season length being dependent on the occurrence of sequences of significant rainfall.

The northern regions of the country have the most regular growing seasons given the more abundant and less variable rainfall elsewhere.

In terms of trend (Fig 22), there seem to be localized areas of (mostly) decreasing trends in duration of the growing season. One large areas occurs in Nampula province, where we will notice a tendency for decreasing vegetation cover as well.

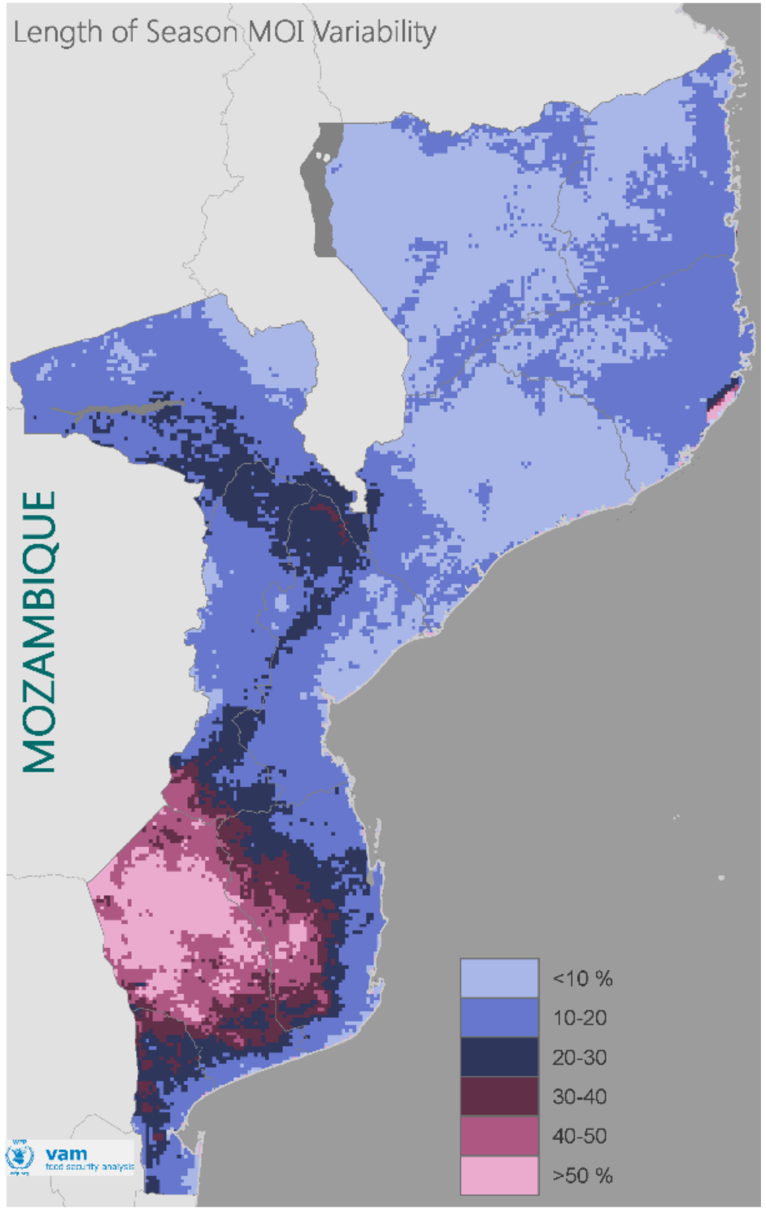


Fig.21 – Variability (CV) in length of growing season

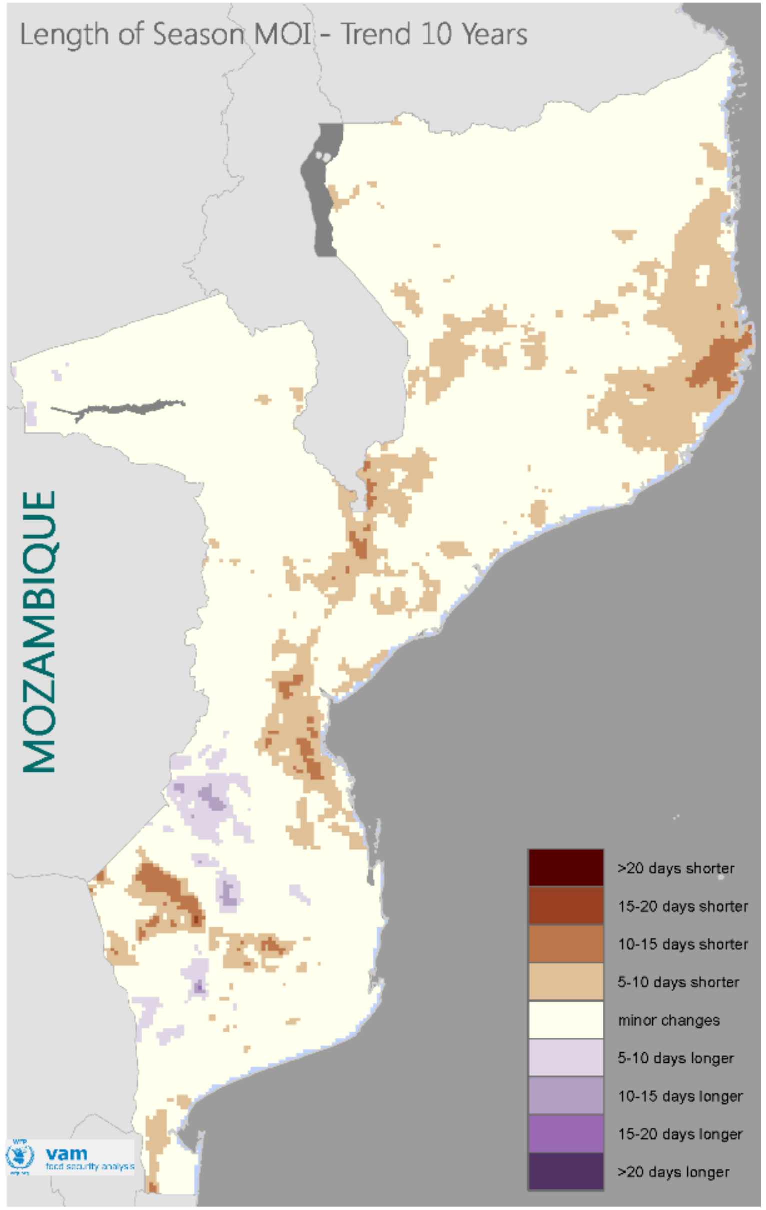


Fig.22 – Trends in length of growing season

NDVI (Vegetation)

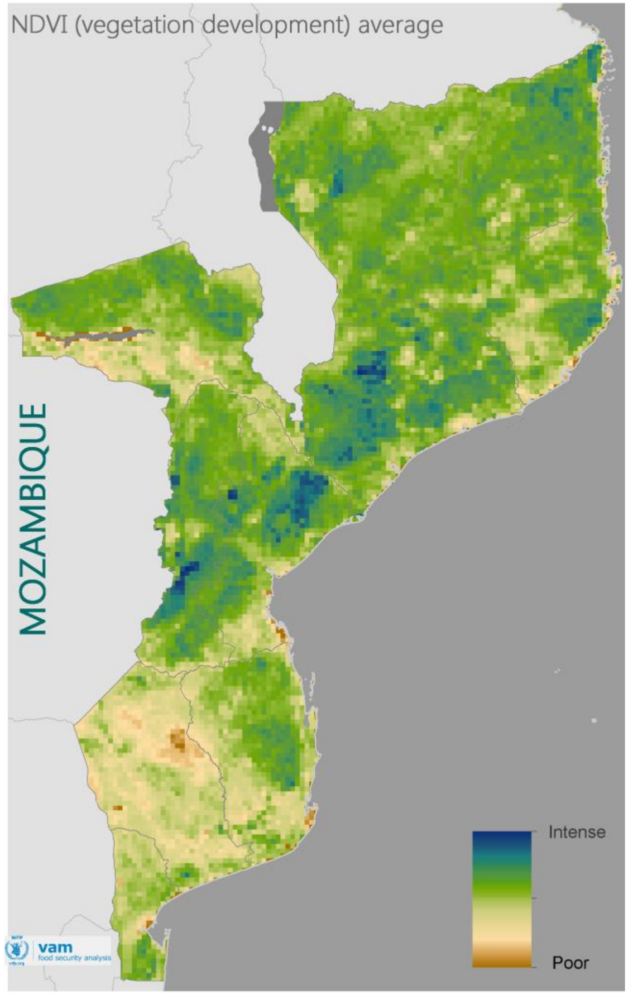


Fig26 – NDVI (vegetation development) average

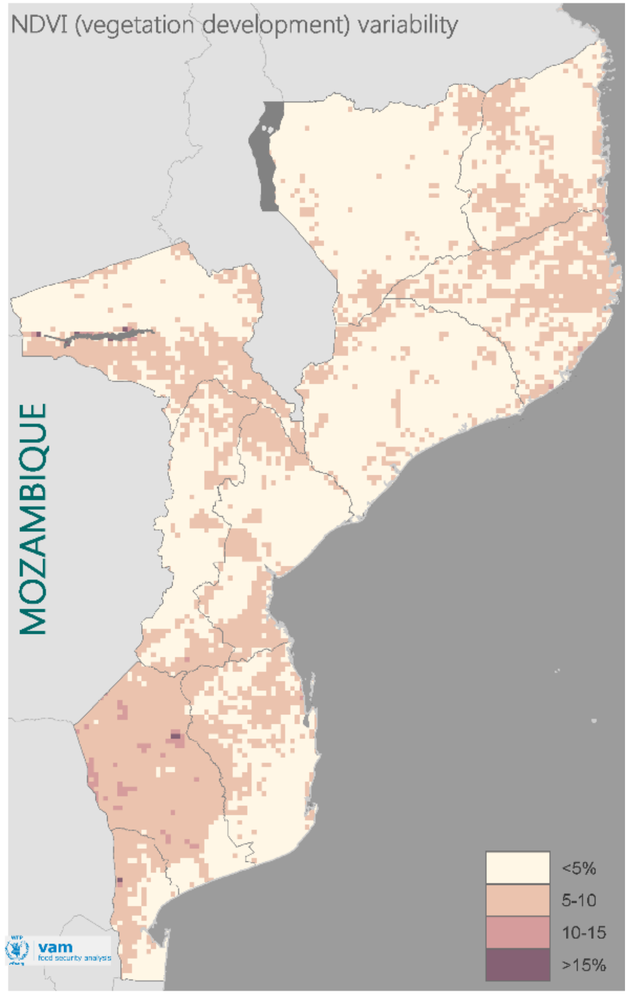
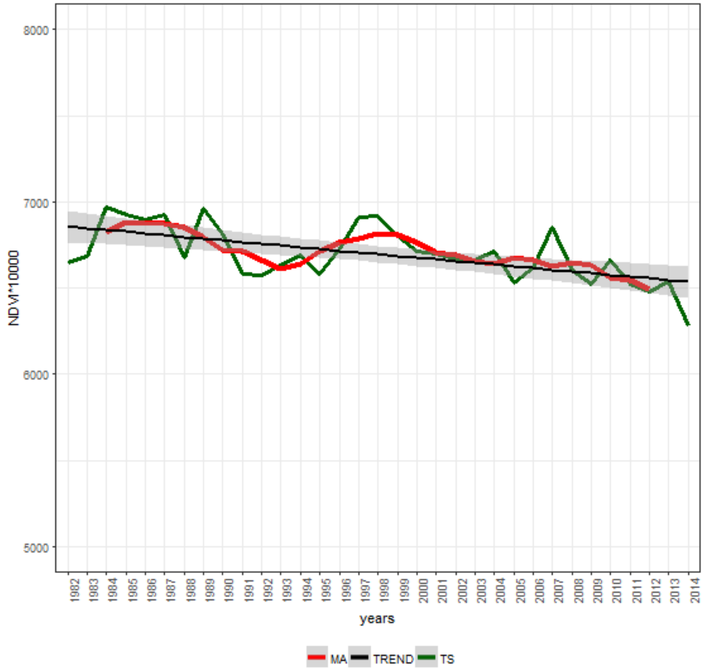


Fig27 – NDVI (vegetation development) variability

Vegetation (NDVI)

Vegetation Index (NDVI) data reflect both amount and health of vegetation. In areas of low rainfall where water is the limiting factor for vegetation growth, seasonal NDVI is closely linked to rainfall; this relationship gets progressively weaker as seasonal rainfall increases and factors other than water availability assume greater importance in controlling vegetation development.

Fig.28 – All-Mozambique seasonal NDVI



Long term seasonal vegetation index is shown in Fig 26. Areas of lower vegetation development are seen in Gaza province and in the southern half of Tete. Strongest vegetation development occurs in the central provinces of Sofala and Zambezia. Inter-annual variability in vegetation development (Fig 27) is strongest in areas where rainfall also displays high inter-annual variability, usually areas with lower seasonal rainfall. Therefore seasonal vegetation is more variable in Gaza and southern Tete province.

One must be careful since long term variations in vegetation development may also arise from changes in land cover, namely conversion of forest or savannah to cropland. Teasing out the drivers of inter-annual vegetation variability is beyond the remit of this analysis.

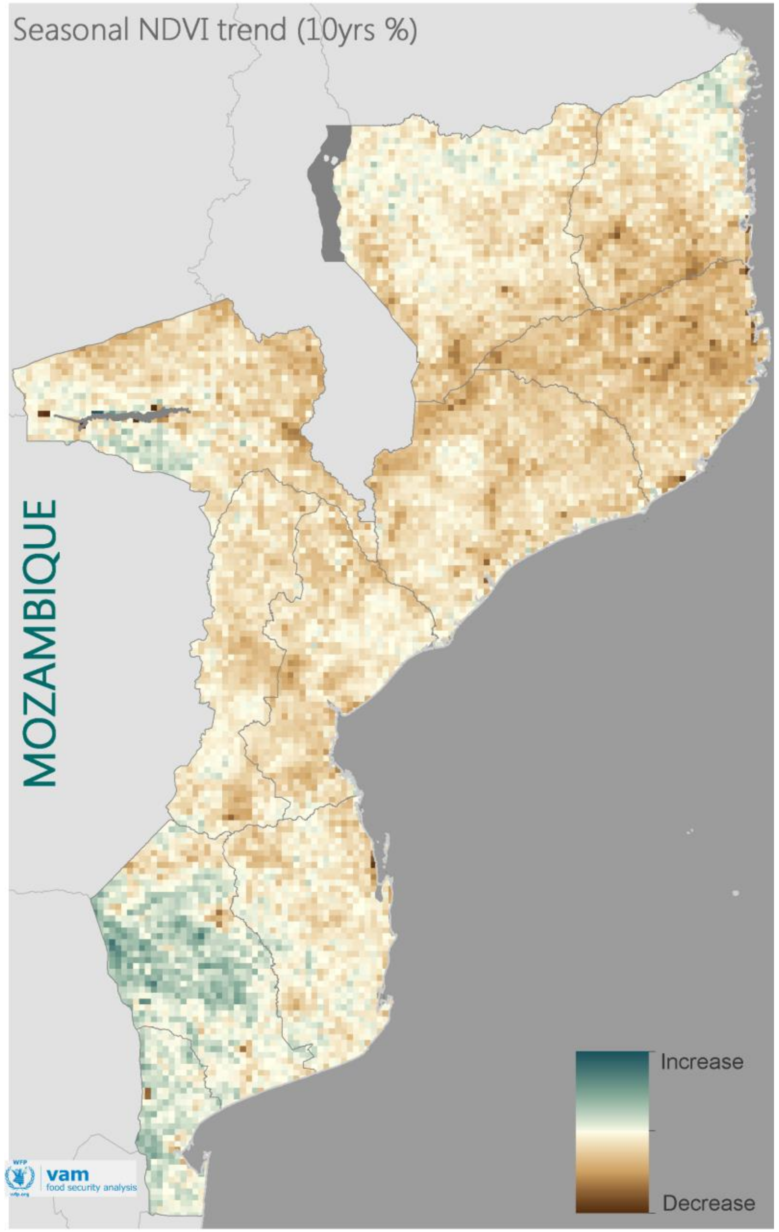


Fig 29 – Seasonal NDVI trend (10yrs %)

Vegetation: Trends

The trend in seasonal vegetation (Fig 29) shows a decreasing tendency across much of the country, particularly in Nampula and Zambezia. In other provinces decreasing vegetation trends are more scattered and less uniform.

Gaza, Maputo and southern Tete are the exception, showing moderate increases in seasonal vegetation.

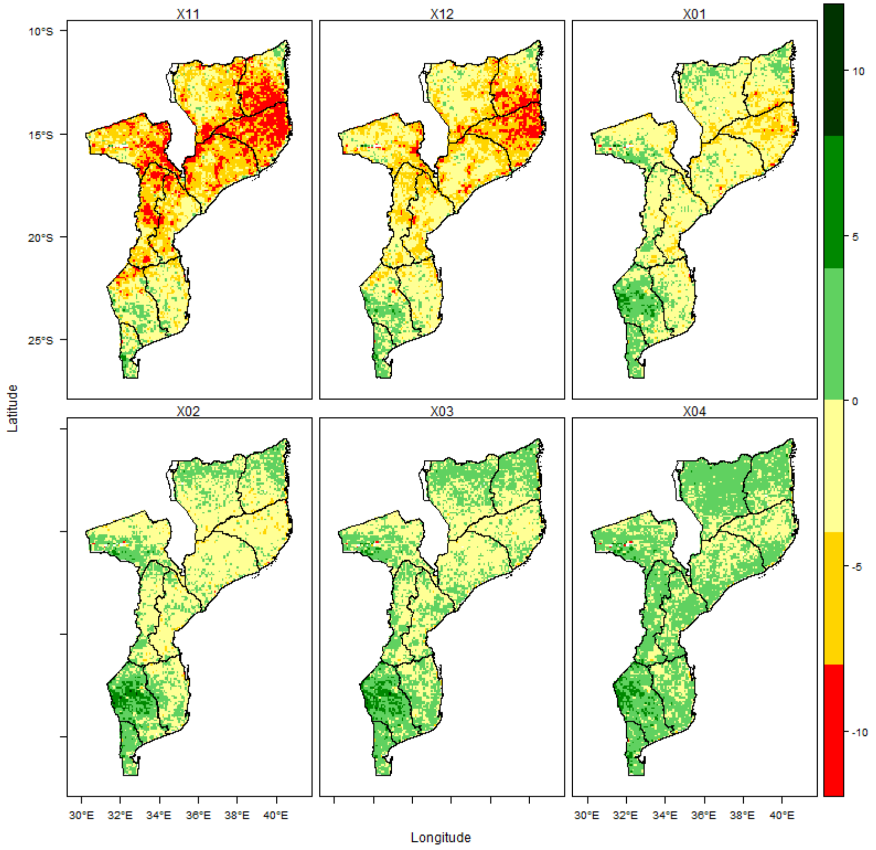
Vegetation: Monthly Trends

Analysing the trend in seasonal vegetation on a monthly basis (Fig 30), shows that across most provinces, except Maputo, Gaza and Inhambane, there are well marked tendencies for decreasing vegetation in the early stages of the season (November and December).

These tendencies get progressively weaker as the season develops. In Tete, Niassa and Cabo Delgado they reverse into moderately increasing vegetation from January onwards.

Gaza and neighbouring provinces to a lesser degree mostly maintain a positive trend in vegetation development throughout the season.

Fig.30 – NDVI monthly trend (%/10yrs)



The negative tendencies in the northern areas of the country will translate in progressively later starts of the seasonal vegetation (or “green season”). This is on agreement with the tendencies of seasonal rainfall and seasonal rain days which also show a decreasing tendency in roughly the same areas.

Vegetation: Monthly trends

The monthly trends were combined into areas of relatively homogeneous behaviour (Fig 32a and 32b).

Zone 2 (orange) includes areas with a decrease in vegetation across the whole season, with the rate of decrease progressively weaker as the season develops.

Zone 3 (blue) has a similar behaviour with a general decrease in vegetation across most of the season, but less pronounced than for Zone 2.

Zone 4 (green) shows a generalized increase in vegetation throughout the season from January onwards.

This agrees with the tendencies for lower rainfall and fewer number of rain days in the more northern areas, which should result in lower vegetation development, in particular during the early stage of vegetation growth.

The two plots in Fig 31 show average NDVI time series for 1985-1995 and for 2005-2015 (first and last 10 year in the available record) to illustrate how the monthly trends translate into changes in the seasonal vegetation profile.

Fig 32a – NDVI monthly trends zoning

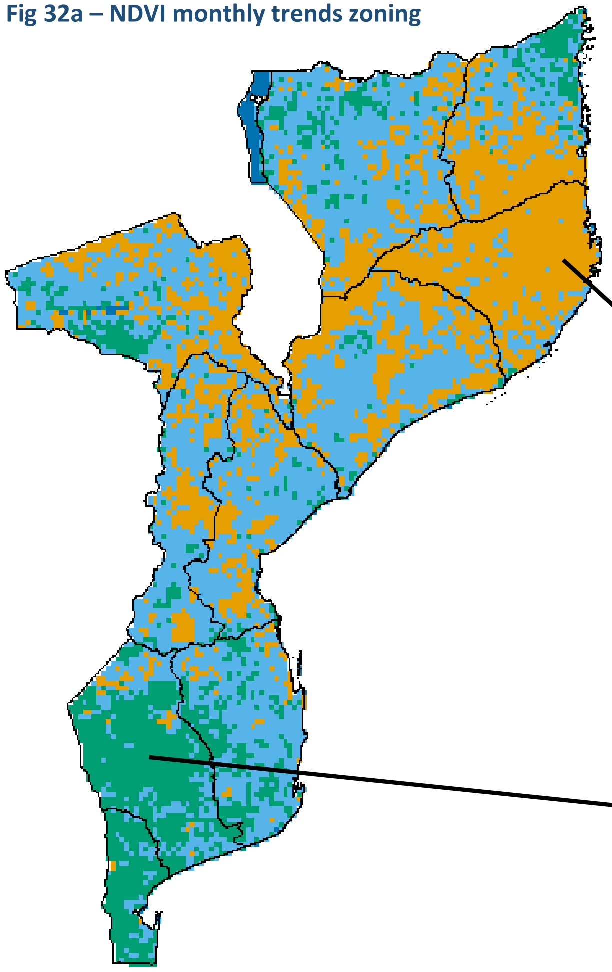
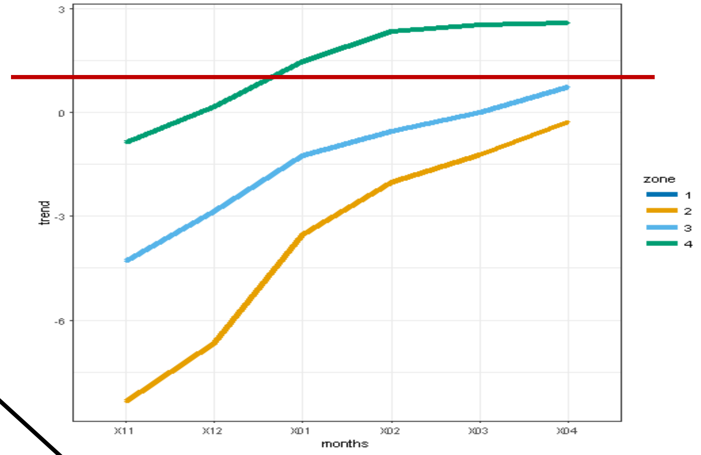


Fig.32b – NDVI zonal monthly trend seasonal evolution



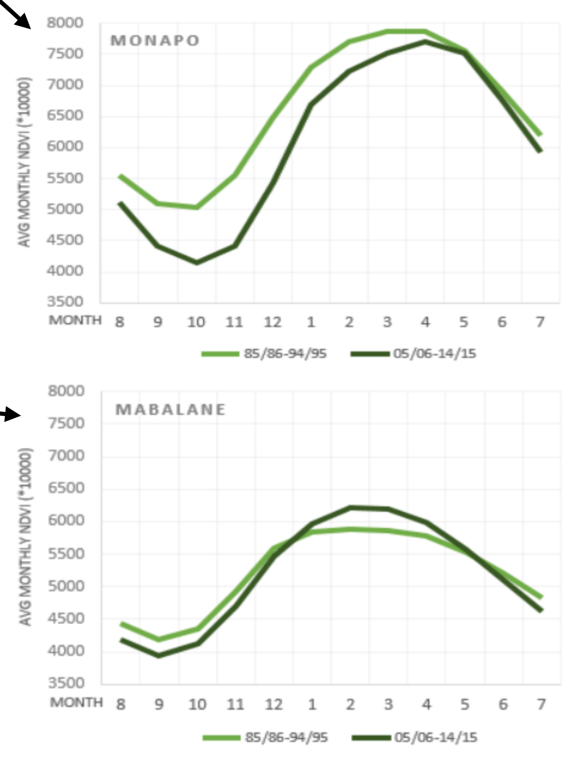


Fig 31 – NDVI profile, early and late record

ENSO PATTERNS

ENSO impacts: Approach

Mozambique, in common with many of Southern Africa’s countries is particularly sensitive to ENSO induced fluctuations in rainfall and hence in vegetation cover.

To map the ENSO impacts for Mozambique, we use an ENSO anomaly approach. Essentially, this compares the averages of a given parameter (seasonal rainfall, temperature in a given month, …) during El Niño and La Niña seasons with the same during neutral seasons:

- Classify each season into El Niño affected, La Niña affected or Neutral.
- Derive averages of a given parameter (e.g. seasonal rainfall) for each of the three groups.
- Compute an anomaly with respect to the average of the neutral seasons.

A negative (positive) anomaly for the El Niño (or La Niña) group would mean that the parameters take on average lower (higher) values in El Niño (or La Niña) affected seasons than in neutral seasons.

This approach was used to analyse ENSO impacts on rainfall amounts, growing season timings and vegetation indices.

El Niño impacts: Rainfall

We first look into changes in rainfall patterns. The figures 33a and 33b show the El Niño anomalies for the three month rainfall OND and JFM, respectively early and peak season rainfall.

The OND rainfall has two distinct patterns: in Cabo Delgado and Niassa, OND rainfall increases in El Niño years, as they are more aligned with East African weather patterns. El Niño enhances rainfall in East Africa down to Tanzania and Northern Mozambique. In contrast, in the southern provinces of Maputo, Gaza and Inhambane, OND rainfall is decreased to less than 70% of the normal in some places. during El Niño years according to the more classic Southern Africa ENSO patterns,

In central regions, OND rainfall remains substantially close to normal during El Niño years.

In JFM, the El Niño effect leads to drier conditions across most of the country. The decrease in rainfall in the south of the country is very pronounced and reaches below 70% of the neutral season amounts. The strongest impacts are in Gaza and Inhambane as well as Manica provinces. In the north (Cabo Delgado, Niassa and Nampula) rainfall during El Niño seasons is on average not significantly different from neutral seasons.

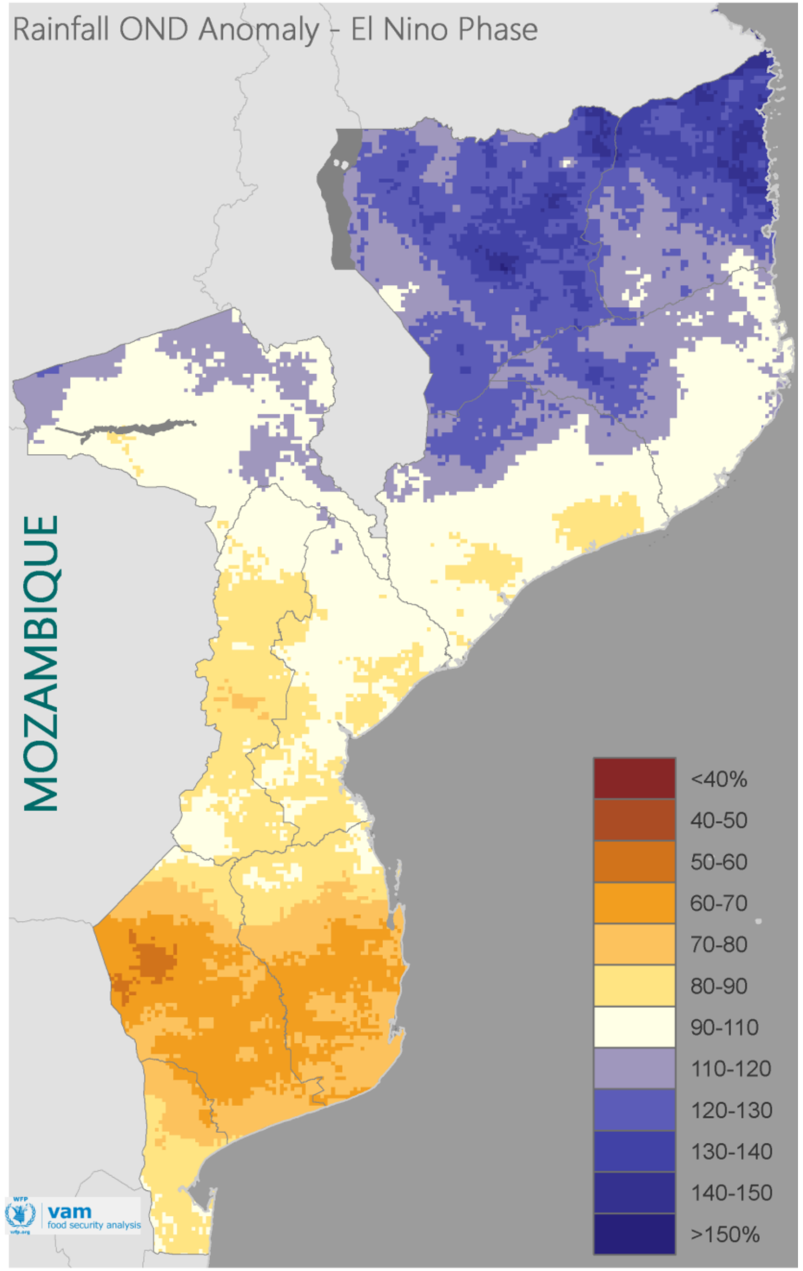


Fig.33a – El Niño Anomaly for OND rainfall

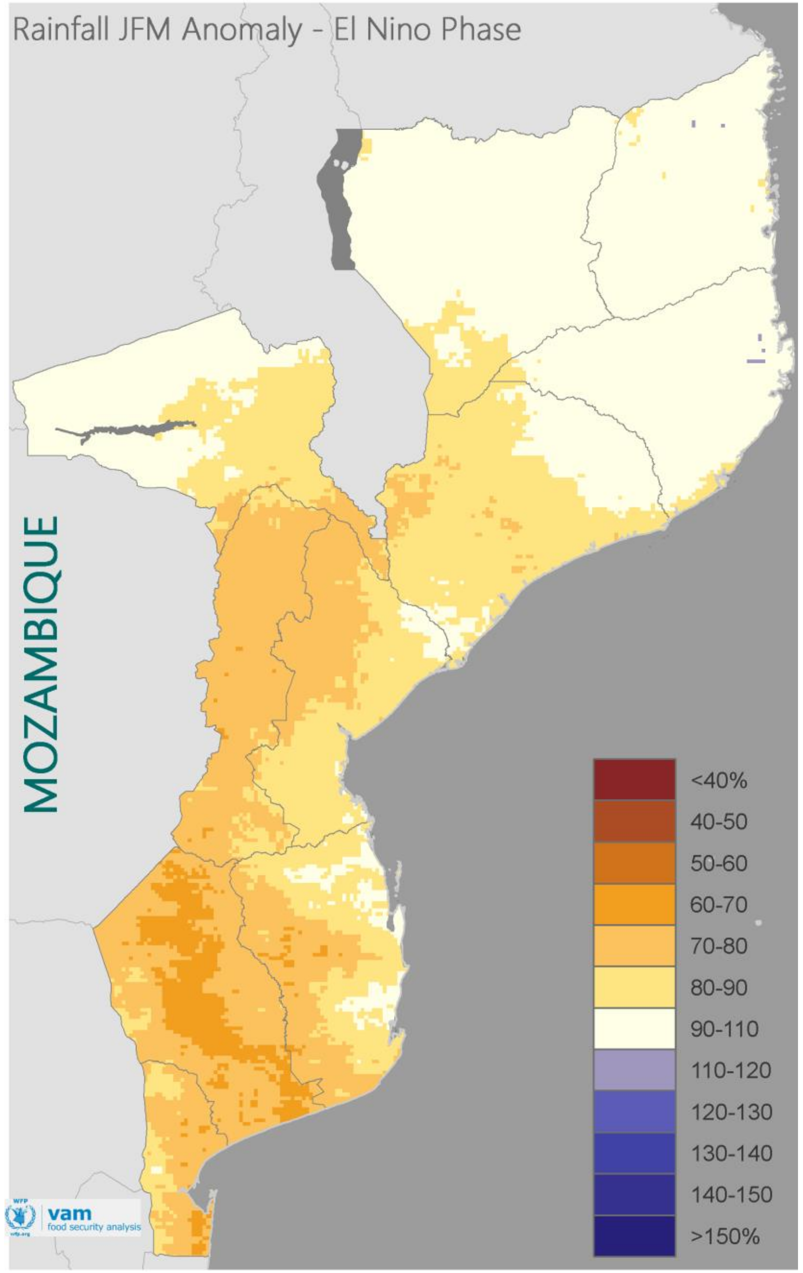


Fig.33b – El Niño Anomaly for JFM rainfall

La Niña impacts: Rainfall

In the case of La Niña, the picture is reversed as rainfall in this ENSO phase tends to be higher than in neutral seasons.

In OND (Fig 34a), there is little discernible impact of La Niña on rainfall, except for the central provinces of Manica, Sofala and northern Inhambane, where early season rainfall is about 10-20% above that of neutral seasons.

In JFM (Fig 34b) La Niña influence is more marked than in OND, but weaker than that of El Niño. The northern provinces see little effect, except for neighbouring areas of Malawi. In the south and centre of the country there is a moderate tendency for increased rainfall. This is more pronounced in Inhambane and western Gaza and Maputo where rainfall is higher by up to 20-30% relative to Neutral seasons.

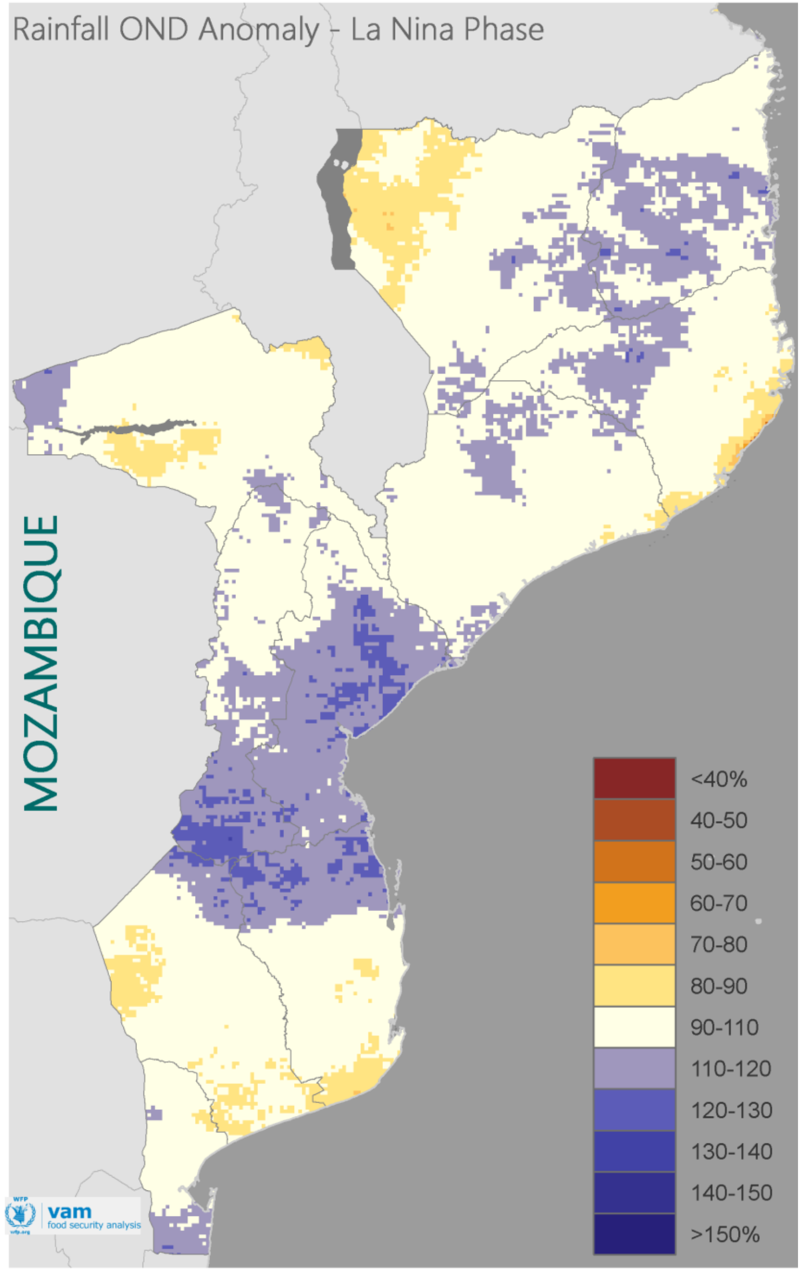


Fig.34a – La Niña Anomaly for OND rainfall

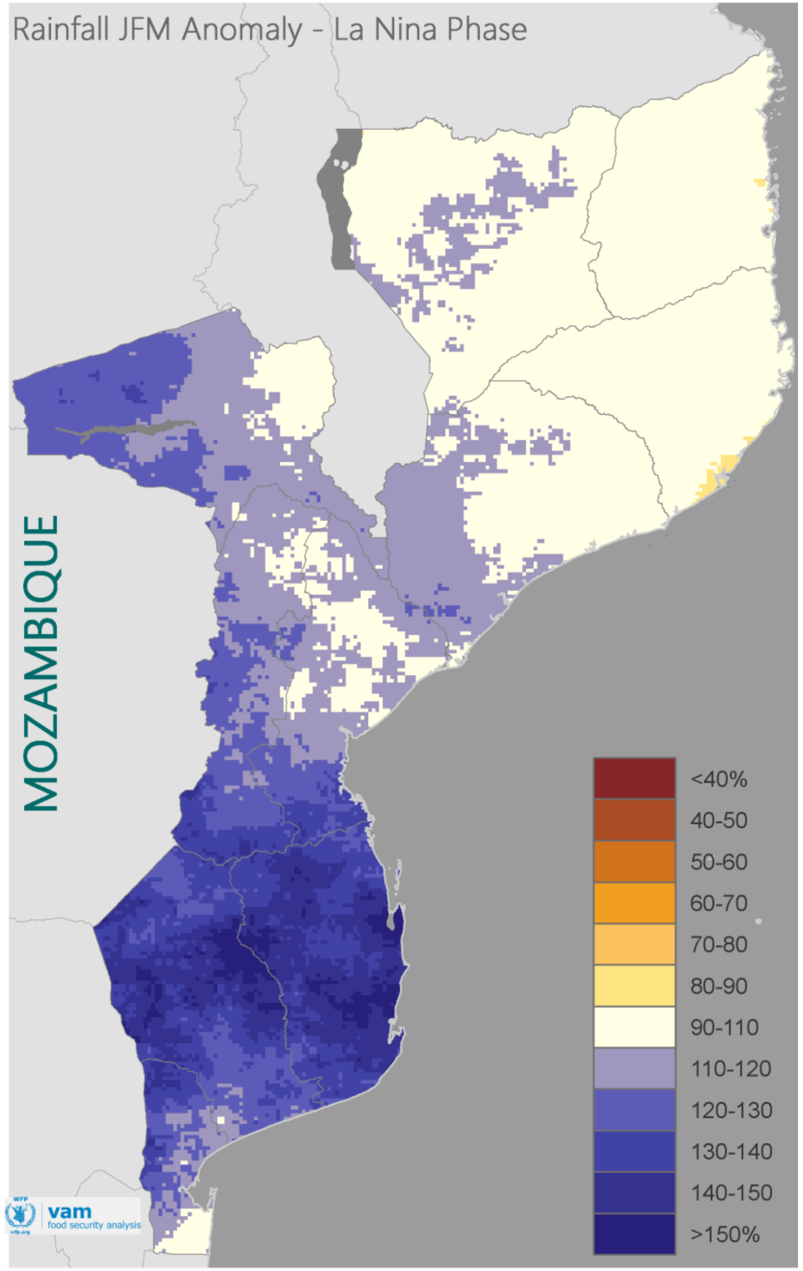


Fig.34b – La Niña Anomaly for JFM rainfall

The maps below show the ENSO anomalies for El Niño (Fig 35a) and La Niña (Fig 35b), for each calendar month. Note that anomalies for the months of June to September are of no significance as this period is outside the main growing season in Mozambique

Fig.35a – El Niño monthly rainfall anomalies

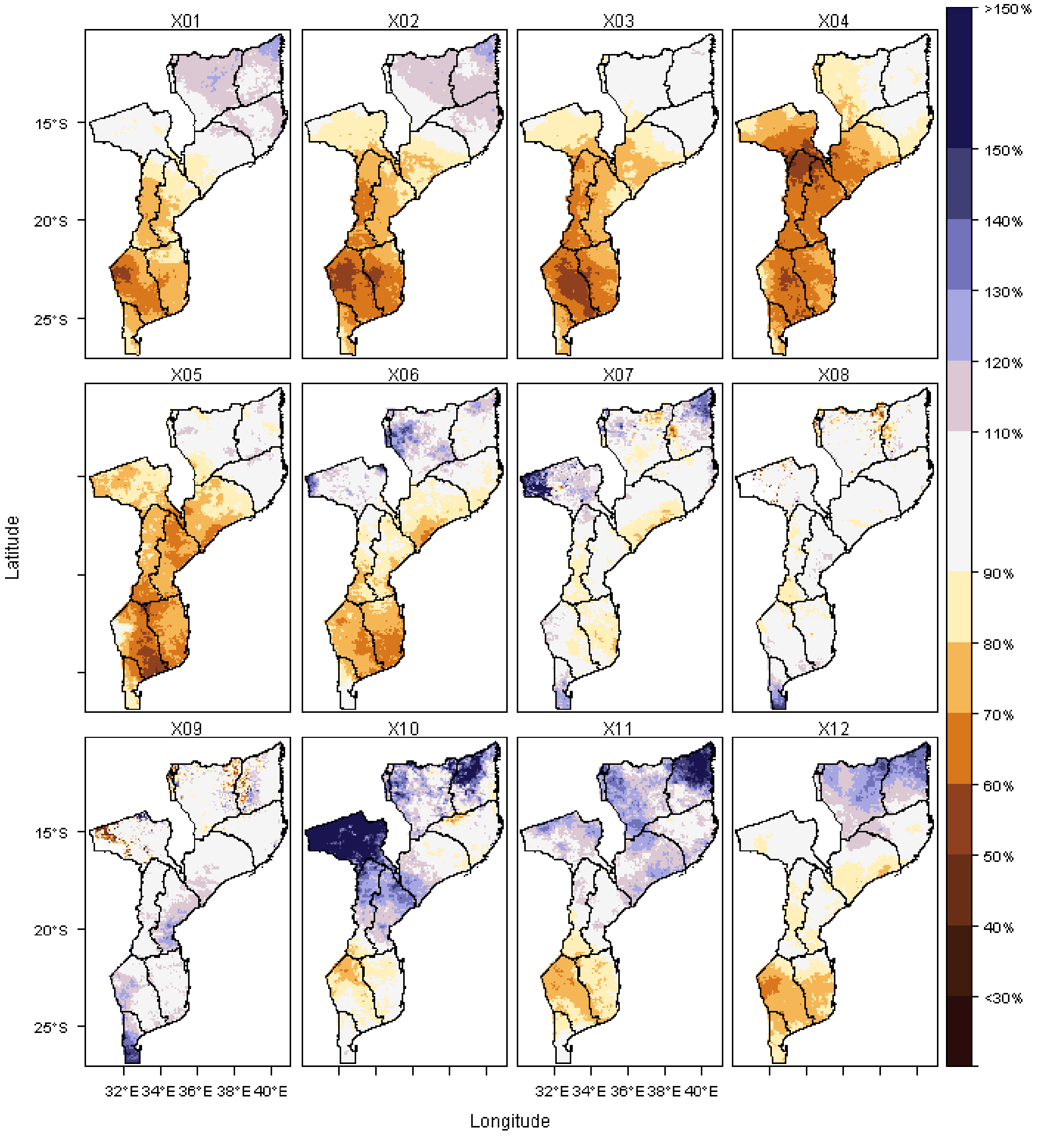
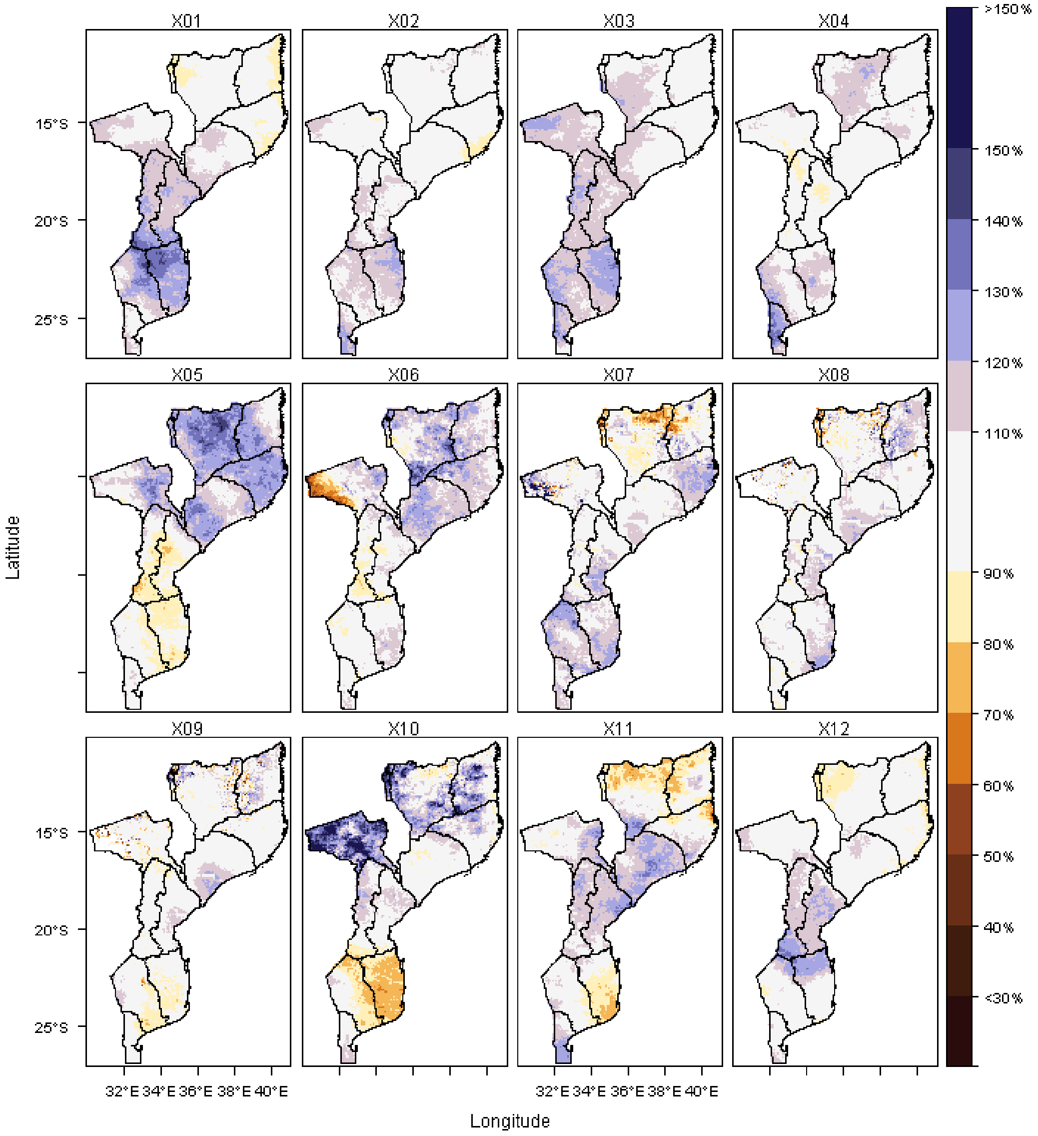


Fig.35b – La Niña monthly rainfall anomalies



El Niño impacts: NDVI

Figures 36a and 36b show the El Niño anomalies for the three month average NDVI Nov-Jan (NDJ) and Feb-Apr (FMA), respectively the early and peak stages of the seasonal vegetation.

NDVI El Niño anomalies show clearly the vegetation response to the El Niño rainfall patterns:

The NDJ mean NDVI shows two main types of variation – In northern provinces and Tete, NDJ mean NDVI is higher in El Niño seasons. In contrast, in Gaza and Inhambane provinces, NDJ NDVI is pronouncedly lower during El Niño seasons than in neutral seasons by as much as 15%, matching the substantial reduction in rainfall.

The FMA mean NDVI during El Niño seasons shows only areas of lower than average values, still more pronounced in southern provinces, but here also extending to Tete. This matches more widespread drier conditions seen in the rainfall anomaly maps.

The use of the mean NDVI in Nov-Jan and Feb-Apr accounts for the fact that vegetation has a slightly delayed response to rainfall.

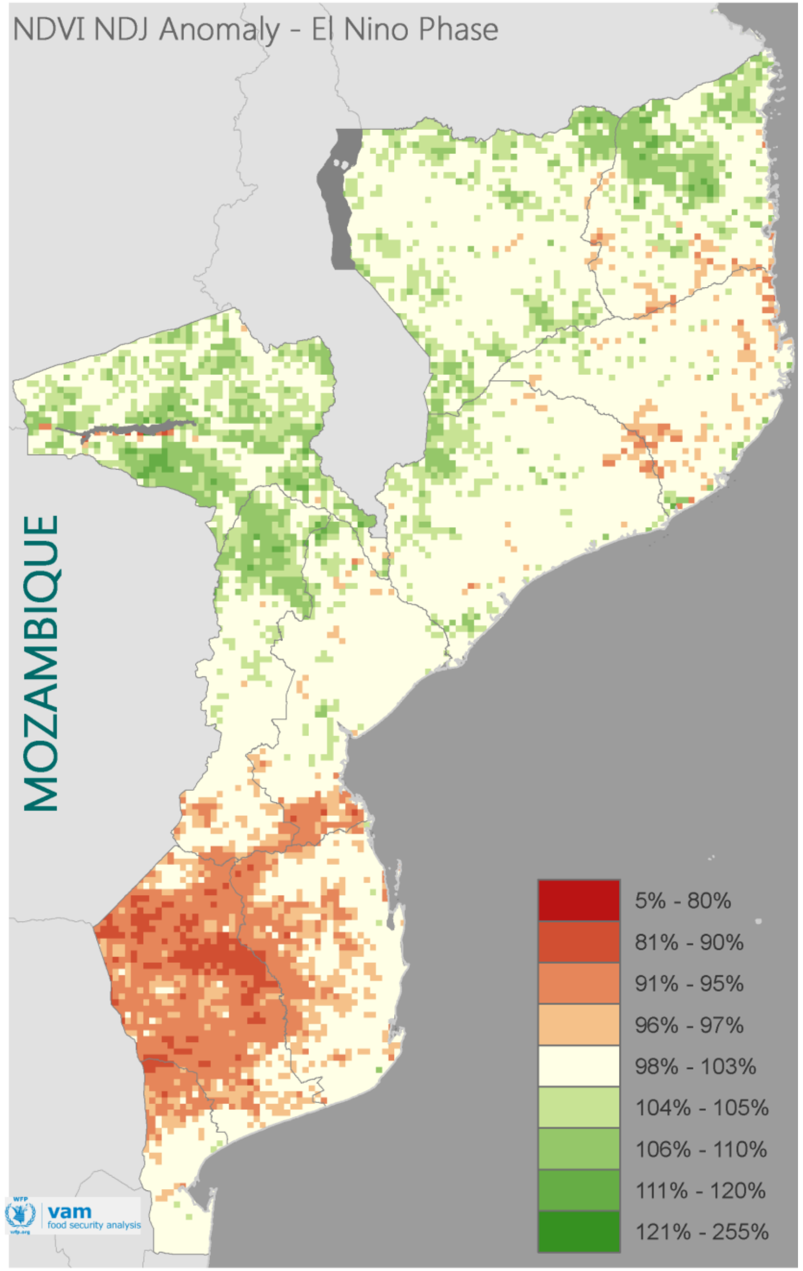


Fig.36a – El Niño anomaly for mean November-January NDVI

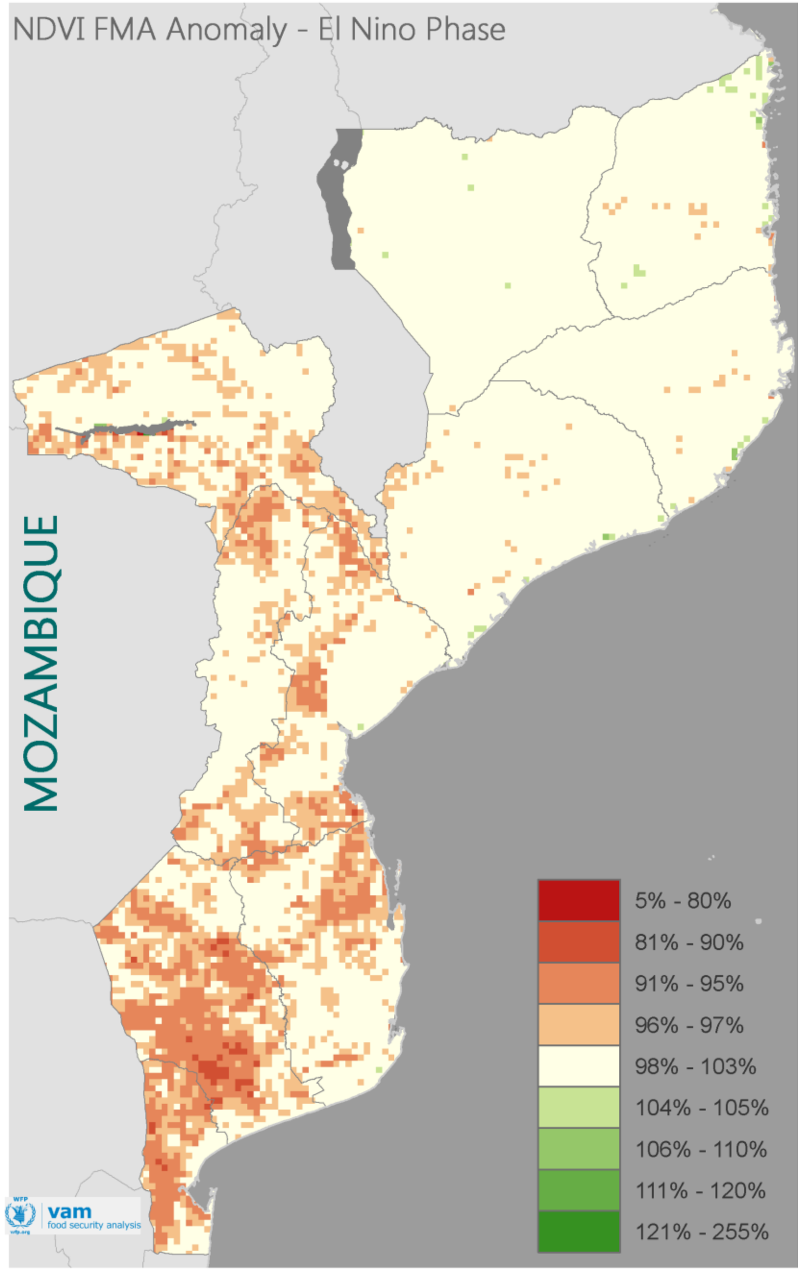


Fig.36b – El Niño anomaly for mean February-April NDVI

La Niña impacts: NDVI

Figures 37a and 37b show the La Niña anomalies for the three month average NDVI Nov-Jan (NDJ) and Feb-Apr (FMA), respectively the early and peak stages of the seasonal vegetation.

NDVI La Niña anomalies are not so clearly linked to the rainfall La Niña patterns:

The NDJ mean NDVI shows lower than usual values in Gaza and Inhambane and also in the two northern coastal provinces (Nampula and Cabo Delgado), with some areas in the Manica-Sofala-Tete showing enhanced vegetation.

The FMA mean NDVI is about similar to that of neutral seasons across the country, though with a noticeable enhancement in Gaza and Maputo provinces in response to the increased rainfall.

The use of the mean NDVI in Nov-Jan and Feb-Apr accounts for the fact that vegetation has a slightly delayed response to rainfall.

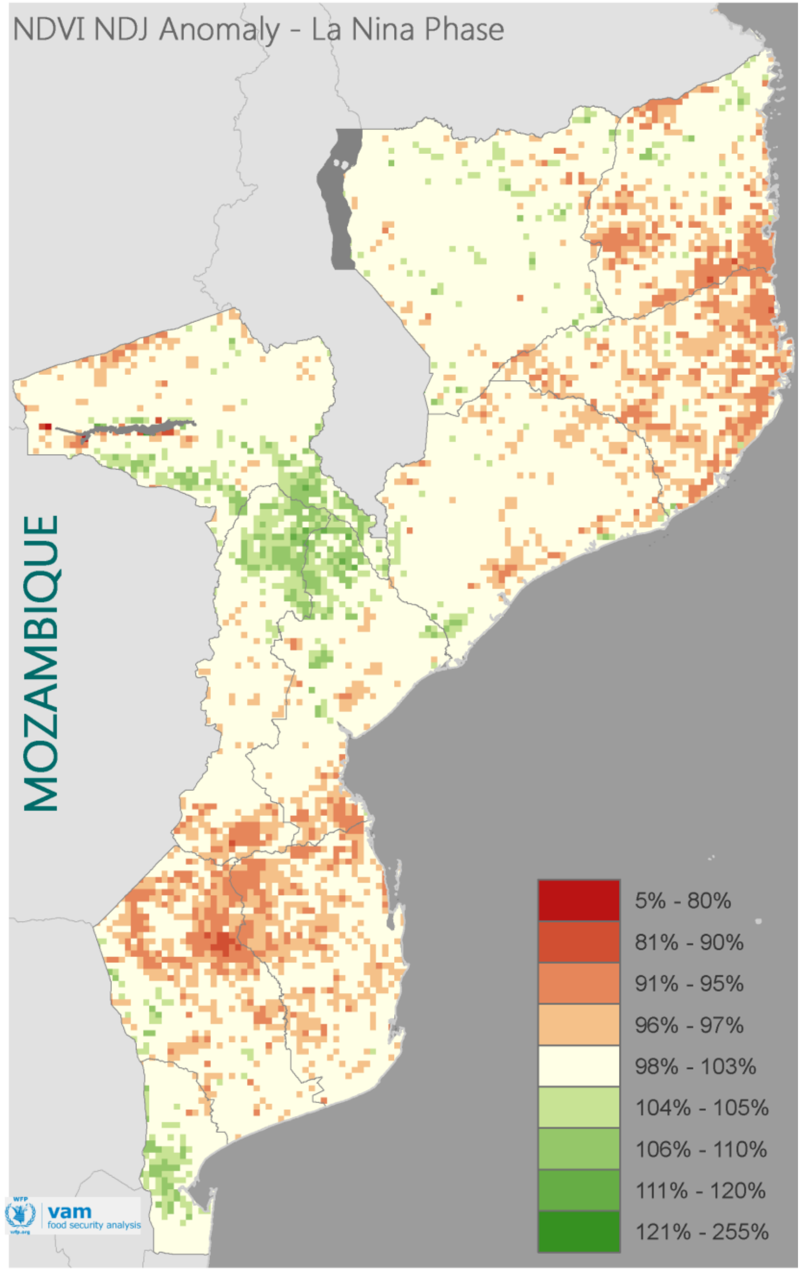


Fig.37a – La Niña anomaly for mean November-January NDVI

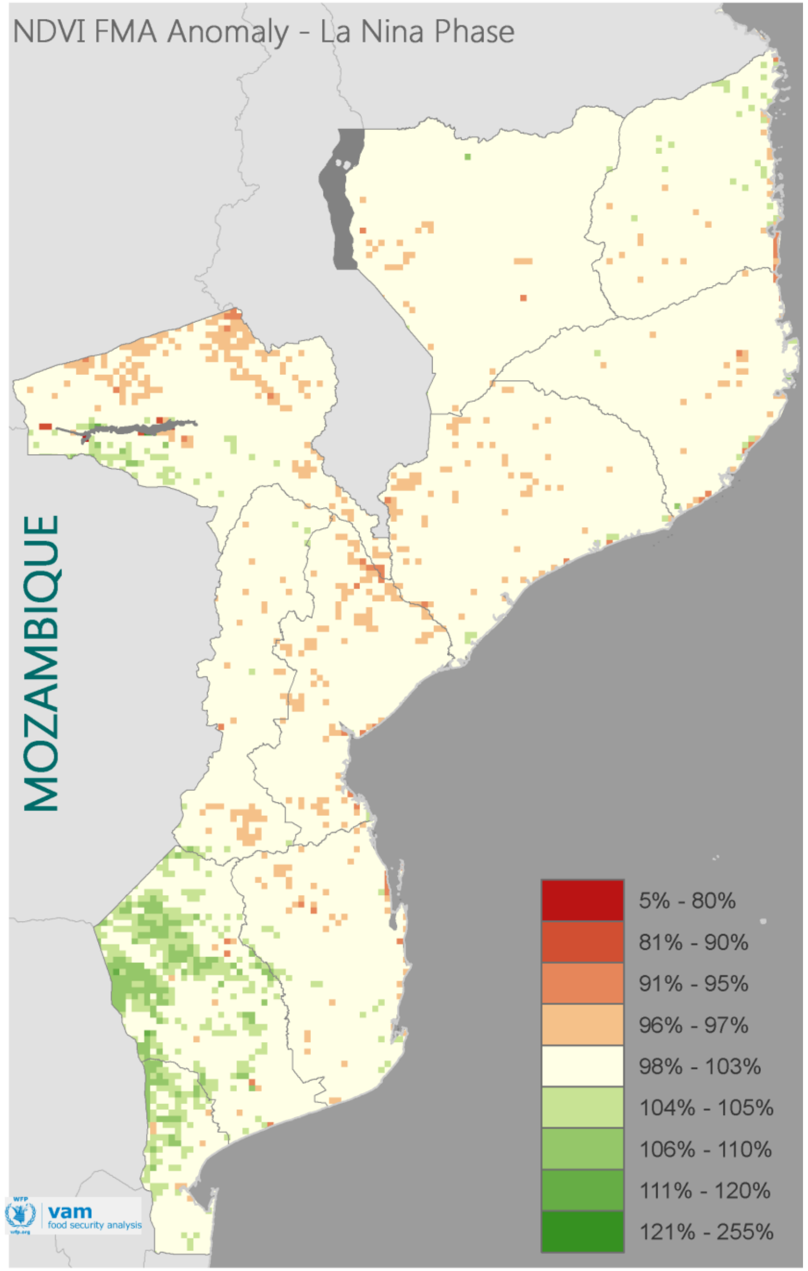


Fig.37b – La Niña anomaly for mean February-April NDVI

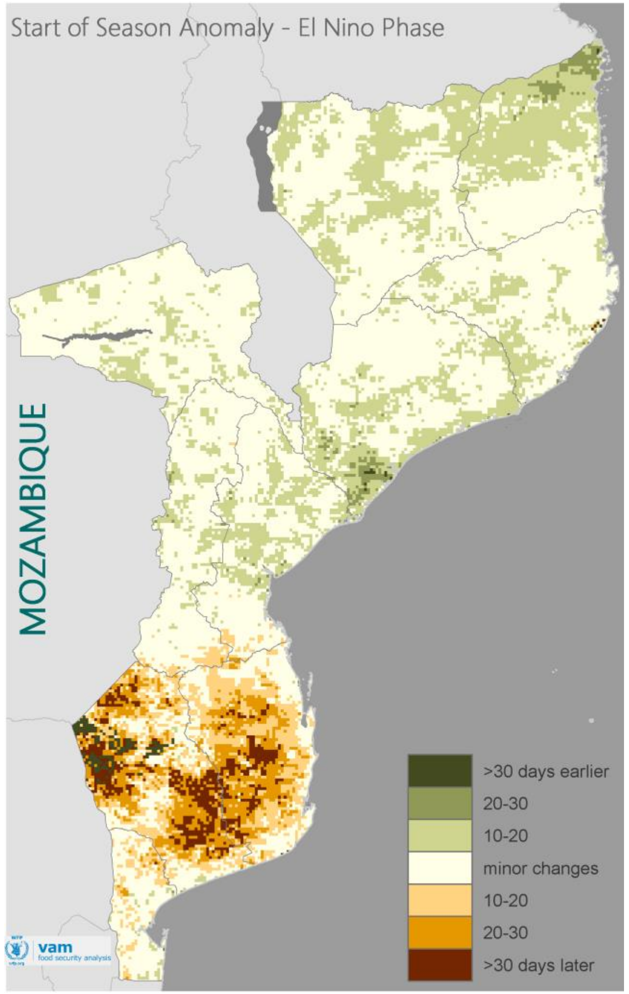


Fig.38a – El Niño anomaly for start of season

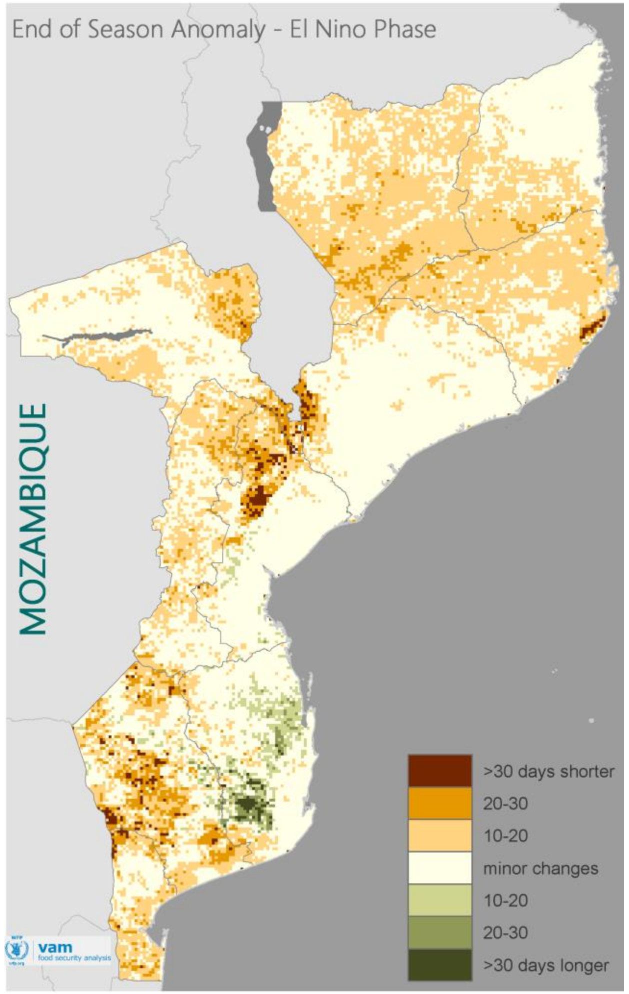


Fig. 38b – El Niño anomaly for end of season

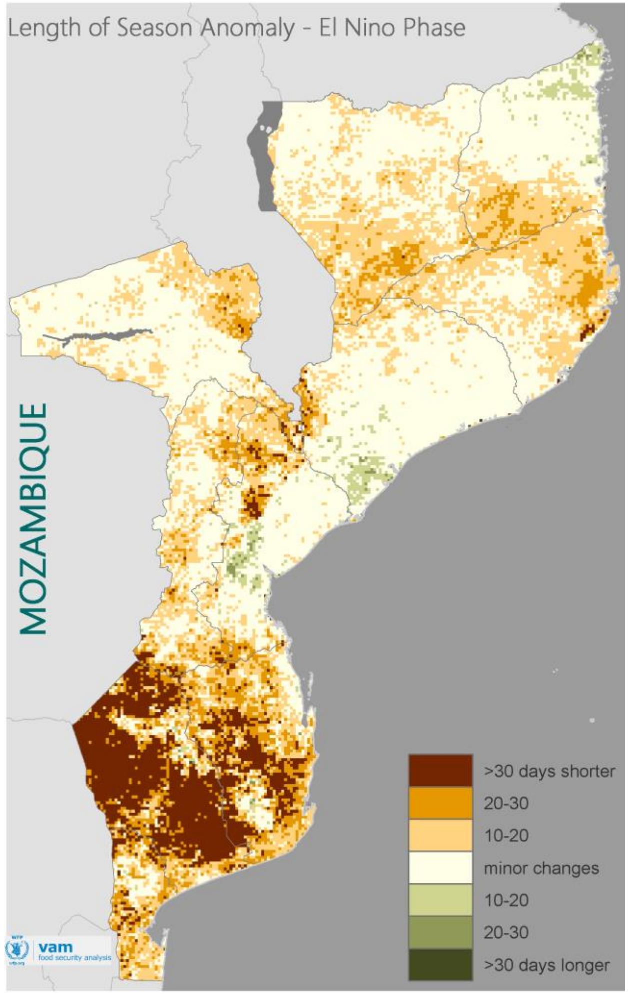


Fig. 38c – El Niño anomaly for length of season

El Niño impacts: Growing Season Timings

El Niño seasons have a marked impact on the timings of the growing season. In Gaza and Inhambane provinces delays can reach one month (Fig 38a). Elsewhere there is either no noticeable impact and a fairly moderate tendency for the season to start earlier due to El Niño enhanced rainfall in the northern areas of the country in the last quarter of the year.

The end of season during El Niño seasons (Fig 38b) tends to occur a bit earlier across most of the country (Zambezia occurred). Altogether, the season is much shorter during El Niño season in the southernmost areas (Gaza, Maputo) and has little variation elsewhere (Fig 38c) .

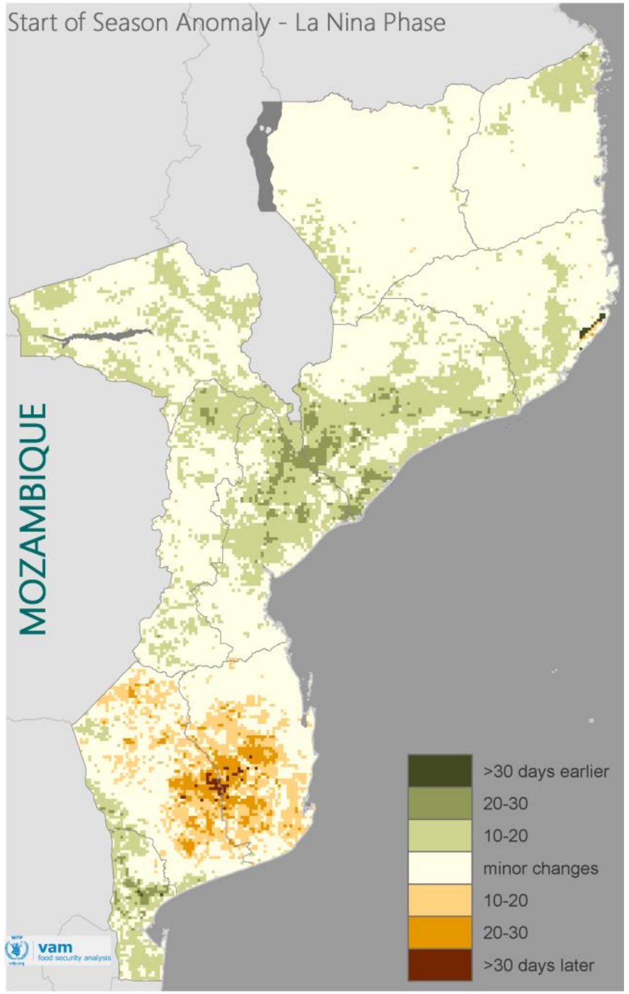


Fig.39a – La Niña Anomaly for start of season

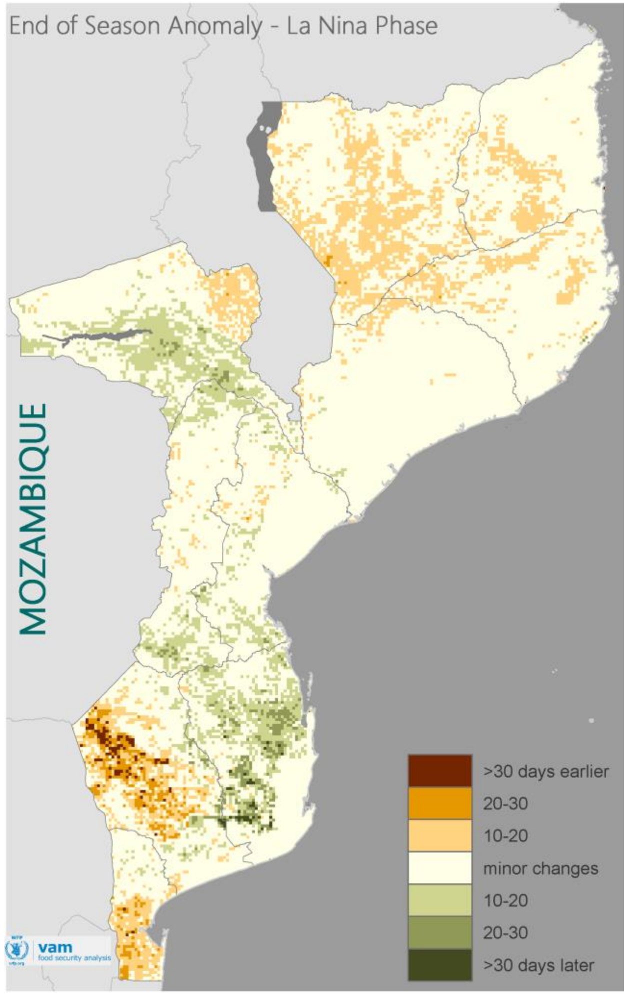


Fig. 39b – La Niña Anomaly for end of season

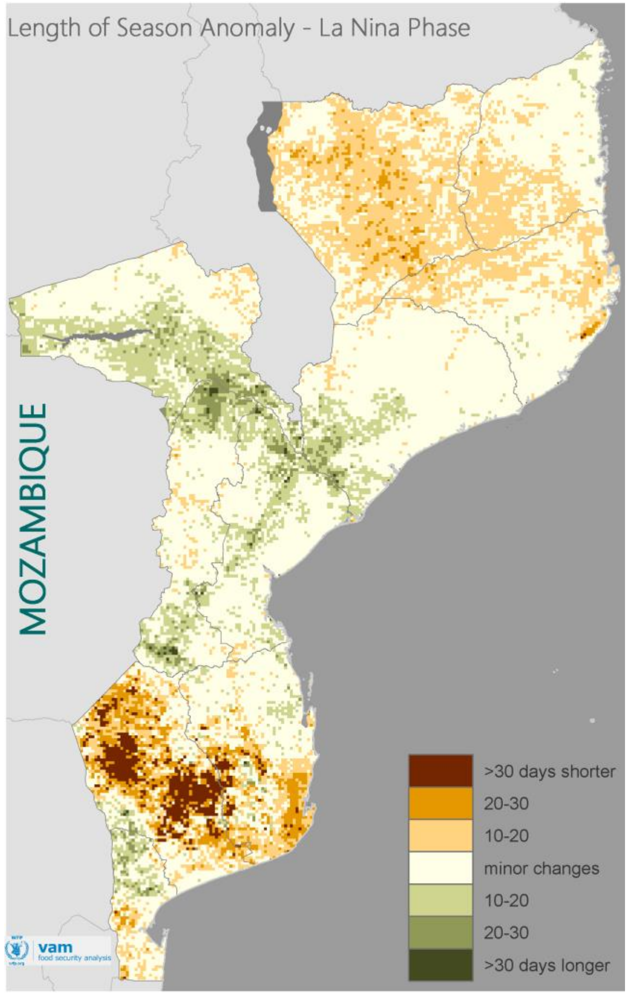


Fig. 39c – La Niña Anomaly for length of season

La Niña impacts: Growing Season Timings

La Niña events result in normal or moderately earlier than usual starts of the season (Fig 39a). The exception is Inhambane and some areas of Gaza where the start of the season is delayed in La Niña seasons. The end of the growing season (Fig 39b)occurs moderately later than usual over an area from Tete to Inhambane, while in Gaza and northern provinces the growing seasons end a bit earlier than usual.

As a result, the length of the growing season in La Niña seasons (Fig 39c) is shorter than usual in Gaza and parts of Inhambane. This is also the case in Niassa and Cabo Delgado. Longer seasons predominate in Tete and in the central provinces of the country.

TEMPERATURE

Temperature: Long Term Average

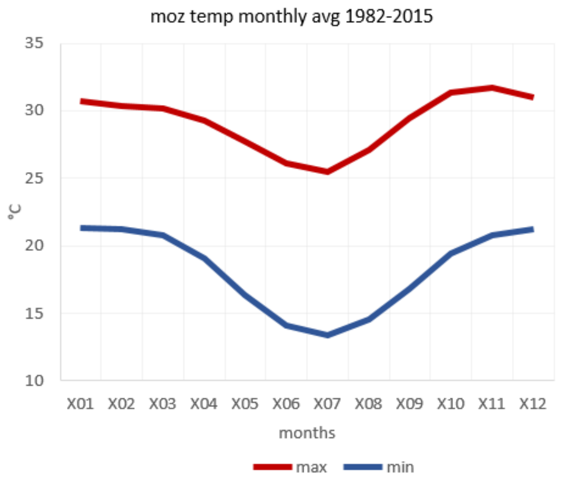
Long term averages of Tmax (Fig 40a) shows highest values in southern half of Tete province. Other warmer areas include the northern coast and western areas of Gaza province.

Tmin (Fig 40b) has a different pattern with a clear gradient of decreasing temperatures from the coast to the interior.

Highest minimum temperatures can be seen along the northern coast, while lowest ones are in western Gaza province. This region also has the wider temperature amplitude in the country.

The country has a simple seasonal temperature profile with a minimum in July (Winter) and a peak in November for Tmax and in December for Tmin.

Fig. 40c – Average max and min temperature



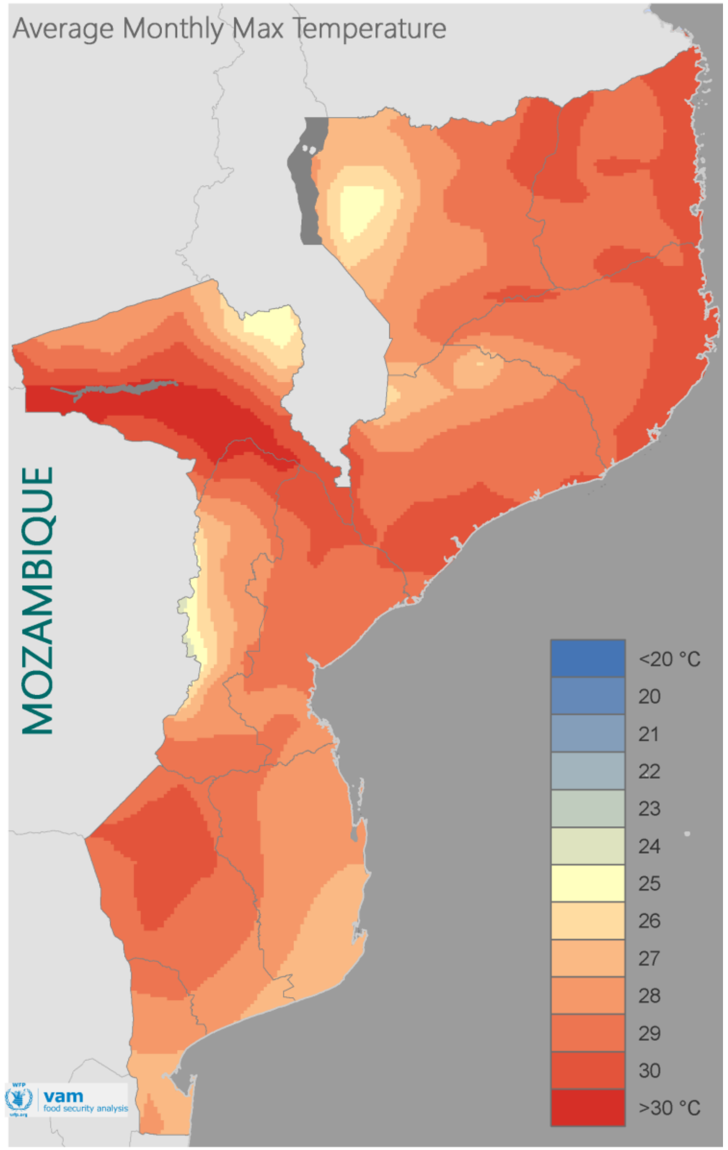


Fig. 40a – Average monthly max temperature

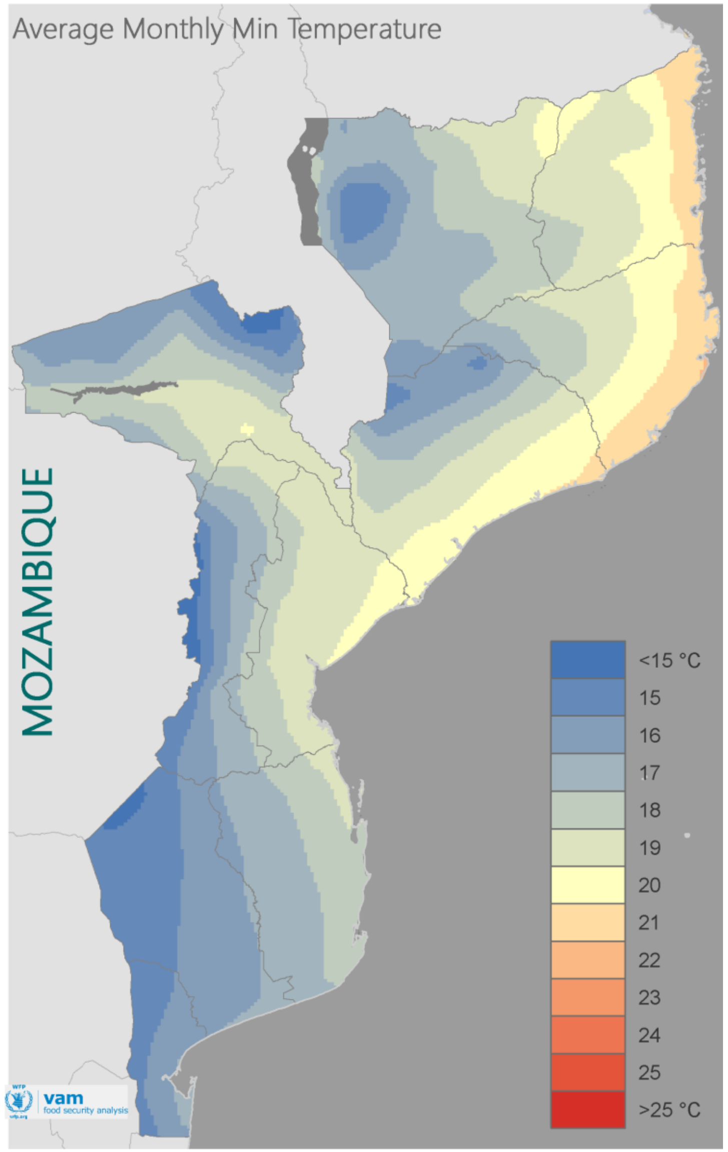


Fig. 40b – Average monthly min temperature

Temperature: Trends

Increases in temperature can impact crops directly in case they reach extremes such that crop physiology suffers. Additionally, higher temperatures raise the water demand imposed on crops by the environment, one of the mechanisms of drought impact.

In Mozambique, an increasing trend in maximum temperature is noticeable (Fig 41a). The trend is higher in the south and west of the country. The minimum temperature in contrast, shows little tendency across the country (Fig 41b).

In any case, these are very moderate trends in particular for minimum temperature. Inter-annual variations are more sizeable and temperature increases coupled with rainfall deficits can have serious impacts on crop development (Fig 42a and 42b)

Fig.42a – All-Mozambique seasonal Tmax

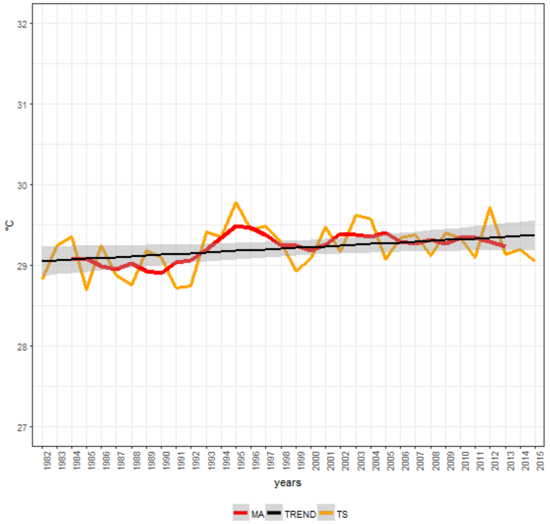
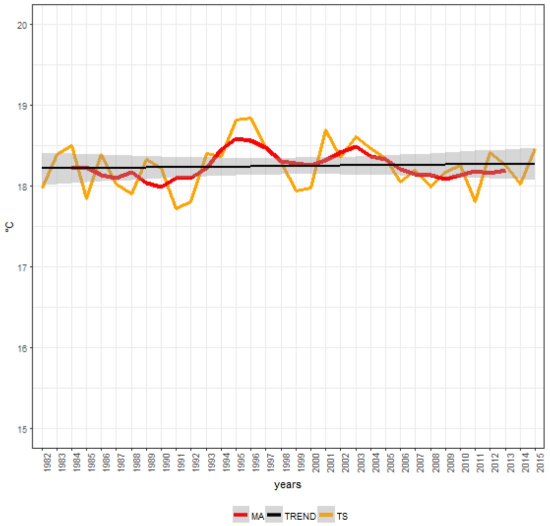


Fig.42b – All-Mozambique seasonal Tmin



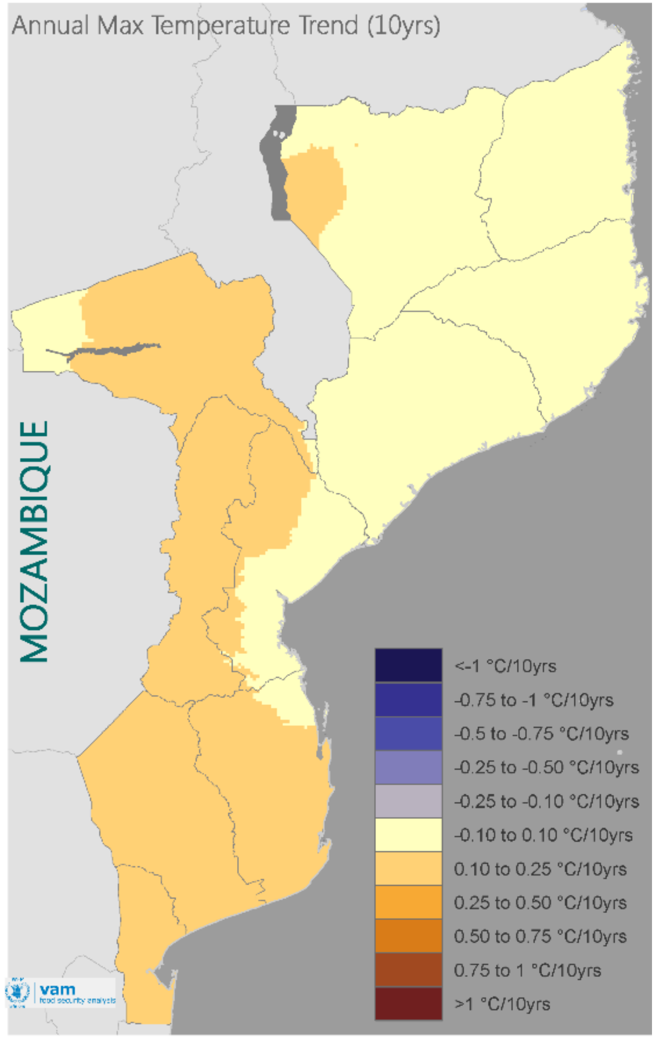


Fig.41a – Annual max temp. trend

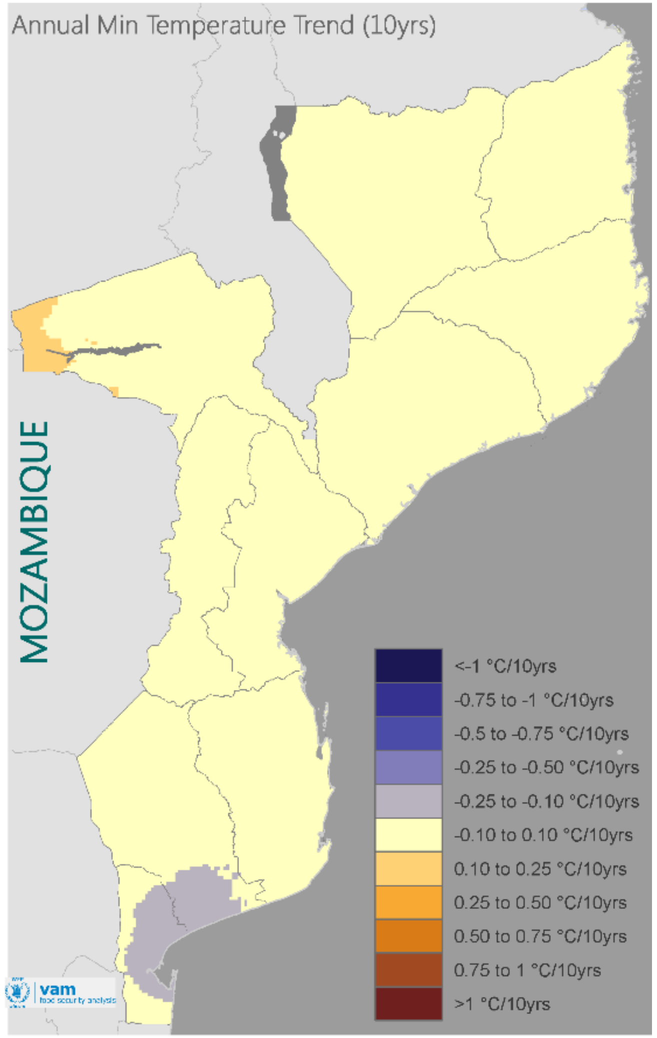


Fig. 41b – Annual min temp. trend

Max Temperature: Monthly trends

Looking at maximum temperature trends on a monthly basis highlights a behaviour common to the whole country – maximum temperature increases are mostly concentrated in October-November and in February-March. Strongest increases occur in Zone 1 (dark blue), i.e. Maputo, Gaza and Inhambane during October and November. The trend is modest (at most 0.4C in 10 years) but may signal a tendency for increased water demand during early stages of crop development.

The northernmost four provinces are those with more modest trends.

Fig.43a – Tmax monthly trends

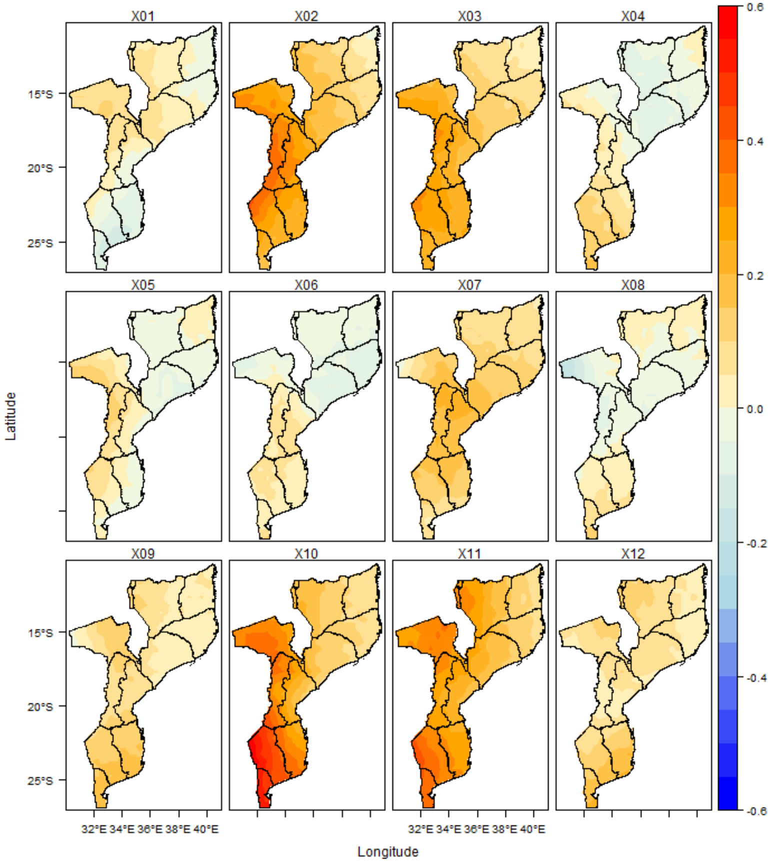


Fig.43b – Tmax monthly trend zoning

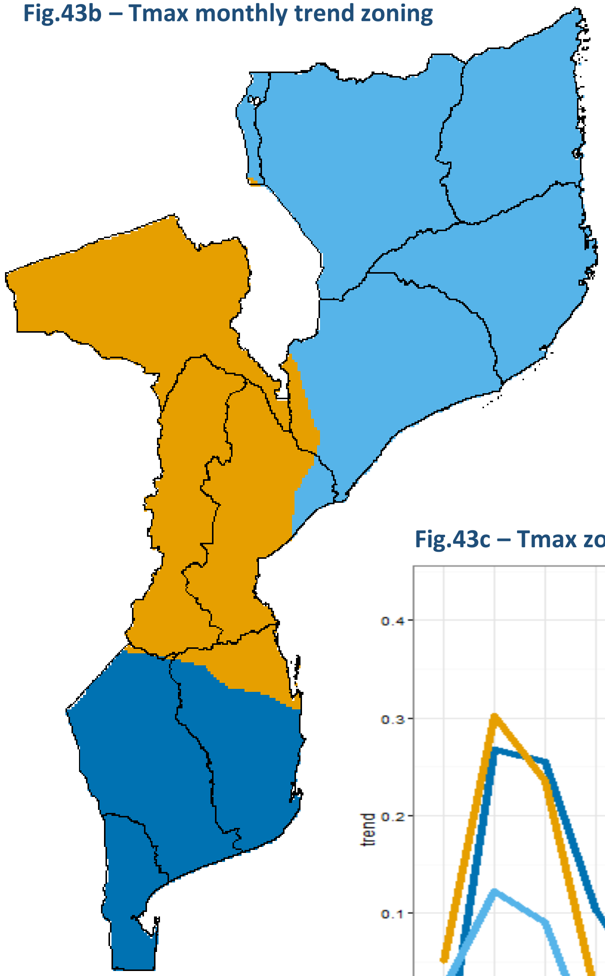
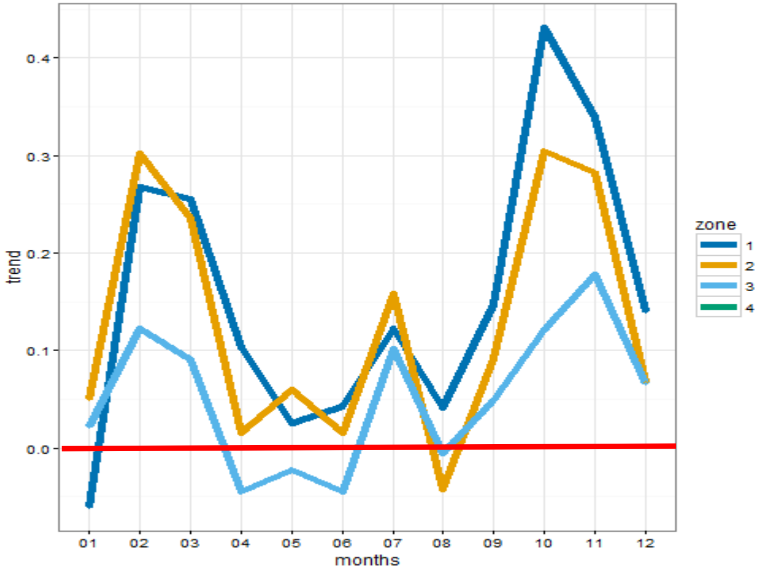


Fig.43c – Tmax zonal monthly trend seasonal evolution



Min Temperature: Monthly trends

Looking at minimum temperature trends on a monthly basis, shows increases in minimum temperature in October-November general to most of the country. This is followed by a decreasing tendency in January in particular in southern Mozambique.

Zone 1 (dark blue) shows mostly a decreasing minimum temperature trends throughout the year, except for moderate increasing tendency in September to November. The other two zones show mostly increasing minimum temperature tendencies, zone 3 (light blue) with very moderate tendencies and Zone 2 (Tete) with increasing minimum temperatures along most of the year.

Fig.44a – Tmin monthly trends

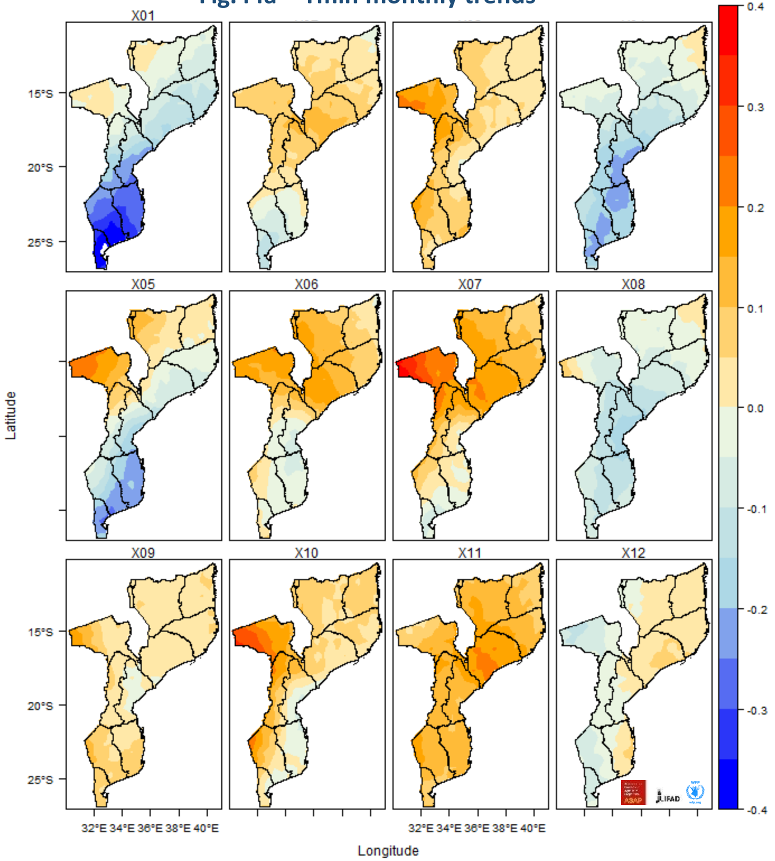


Fig.44b – Tmax monthly trend zoning

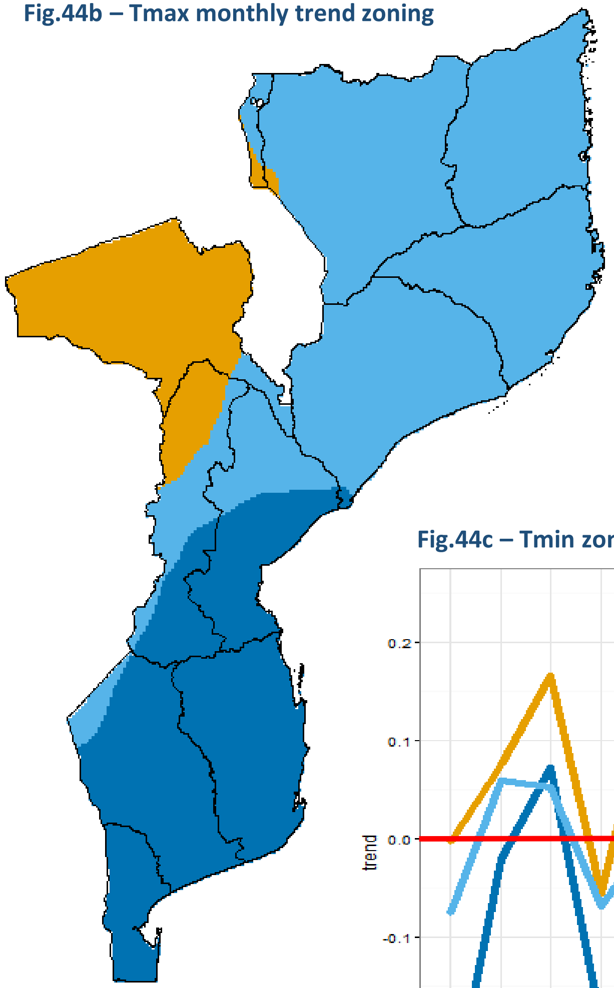
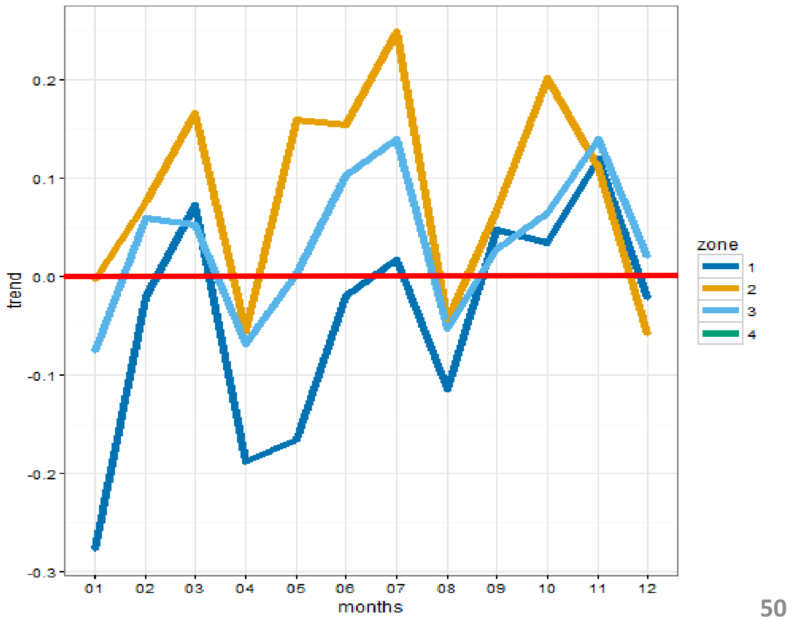


Fig.44c – Tmin zonal monthly trend seasonal evolution



THE END

May 2018

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