# TIME SERIES ANALYSIS OF CLIMATE CHANGE, DROUGHT AND FOOD SECURITY NEXUS IN KADUNA STATE NIGERIA


## Abstract

The tripartite interplay of drought, climate change and food security have for some time been investigated but the complexity of unfamiliar, local or regional climatic diversities have made it difficult to come to a universal understand of the trio. Kaduna state is located within the Sahelian part of Nigeria, a drought prone region making it a region of concern in view of devastating climate dynamics in recent times. The study examined the interplay of drought, climate change and foo security and the resultant effects. The study employed the use of special datasets specifically and solely designed for effective monitoring of drought by the European Commission (EC) and the United States Agency for International Development (USAID) Joint Research Centre (JRC). The research bodies developed the Software for Processing and Interpreting Remotely Sensed Image Time Series (SPIRITS), a standalone yet robust software for detecting and interpreting the dynamics of vegetation and climatic variables. Vegetation anomaly was evaluated and presented as absolute and standardized change images**.** High degree of vegetation anomalies was recorded mostly in decreasing manner of about 73 and 80 percent of the time and total area respectively with only 27 percent of the study area witnessing increasing vegetation occurring largely in the southern part of the state notably Sanga, Kaura, Jema'a, Zango Kataf, Chikun, Jere and Kachia LGAs. This results in consistent decrease in vegetation with a negative effect on food security. The study therefore recommends handsome reward for tree planting and adequate sanction for cutting down of trees. Wild fire early warning systems should be developed and implemented and the capacity of disaster early warning systems should be strengthened with adequate funding.

## 1. INTRODUCTION

Climate change has over time and space showed a variety of effects, including decreased rainfall in dry climates and increased rainfall in humid climates. These result in frequent and irregular drought regimes and crop failure in drier climes, such as the northern parts of Nigeria. More than any other characteristic, vegetation anomaly indicates a decrease in rainfall (Wu et al., 2021). According to Sykes (2009), five major drivers of change that will alter global vegetation during the next 100 years; landuse change been the most significant driver of change globally, followed by climate change. As a result, it has been advised that it is critical for countries to assess the likelihood that drought would strike all or some of their key crop-producing regions or river basins at the same time, and to plan for such an event. Models of climate change have anticipated global warming in addition to changes in precipitation regimes, which affect the timing, frequency, and intensity of precipitation episodes (Morfopoulos*et.al.* 2022). Drought frequency, duration and severity may increase as a result of this, particularly in drought-prone areas of the world (Seile*et al.* 2022). The productivity, composition, variety, and spatial extent of ecosystems, as well as plant dominance patterns and community evenness, will all alter when climatic zones change owing to climate change (Suffling& Scott, 2002).

Increasing temperatures and severe droughts have resulted in high mortality in mountain or high-latitude plant communities' trailing range edges, causing rapid range shifts and range boundary disturbances, species replacement, and community alterations (Friedlingstein*et.al.*, 2022). Across various climates, these changes may have an impact on food distribution, culminating in extinction. Furthermore, the terrestrial carbon budget is linked to $CO_2$ concentrations in the atmosphere (Friedlingstein et al., 2019; Le Quéré et al., 2018; Piao et al., 2020). The terrestrial carbon budget and climate interact at multiple temporal and spatial scales (Friedlingstein et al., 2019; Le Quéré et al., 2018 Scher and Messori, 2019; Rödenbeck et al., 2018): there are very local effects, for example, hourly to seasonal small-scale direct drivers that affect precipitation (Homyak et al., 2018) and gross productivities (Novick et al., 2016) and subseasonal or longer effects at the regional to continental scales, for example, the coupling between large-scale vegetation greenness and teleconnection indices such as the El Niño – Southern Oscillation (ENSO) (Bowman et al., 2017) or the North Atlantic Oscillation (NAO) (Gonsamo et al., 2012).

Climate change may cause vegetation to shift and ecosystems to be disrupted (Gonzalez et al., 2010). Field observations in boreal, temperate and tropical ecosystems for instance have detected biome changes in the 20th century. According to the study,one-tenth to one-half of global land may be highly to very highly vulnerable to climate change. Vegetationhas been shown to respond strongly to many of the drivers which are predicted to change natural systems over this century, including climate and other anthropogenic influences (Lawal *et al.,* 2022). FAO (2012) reported that malnourishment in the sub-Saharan region of Africa has been on the increase since 1990. This may be linked to the food insecurity, which is aggravated by declining precipitation, climate change and population increase. Food security is of fundamental importance for human existence. Changes in the frequency and severity of extreme weather events have a significant impact on agriculture. Crop management, agricultural output and quality, and the development of crop diseases and pests can all be influenced by the weather. Future climate data is so critical for adapting to the effects of climatic variability while also enhancing the quality and amount of production. (Jenkins *et. al*,2021). Climate predictions and projections can aid with long-term decisions such as whether new crop types should be produced or whether new water management and irrigation infrastructure will be required.

Climate unpredictability and change, according to Lawal *et al.,* (2022) has been projected to jeopardize agricultural production and food access in several African countries by 2020. The area suitable for agriculture, the length of the growing season, and production potentials are predicted to diminish, particularly around the edges of Africa's arid and semi-arid regions. Rain-fed agriculture output in some African countries could be cut by as much as 50%. This would have a negative impact on food security in Africa and worsen malnutrition (Sawa, Ati, Jaiyeoba and Oladipo, 2015). Because most African economies are centered on agriculture (Pius, 2021), a bigger share of drought difficulties will wreak havoc on agriculture, particularly in rural regions, as a result of poverty-related agricultural practices and other land use systems worsened by climate change and drought dynamics (Winkler *et.al.*, 2021). Inappropriate farming systems, such as continuous cultivation without any supplements, overgrazing, poor land management practices, a lack of soil and water conservation structures, and a high incidence of indiscriminate bushfires, contribute to land degradation and exacerbate the drought and desertification process especially in the African continent.

Jonathan et al. (2014) found evidence indicating an increase in the number of droughts around the world as global warming causes higher temperatures and exacerbates dry conditions. Sheffield et al. (2011) came to similar conclusions, albeit with a smaller rise in worldwide drought frequency (DF). Drought has been a more common element of the European climate in recent decades, and it is not limited to the Mediterranean region, as droughts can occur in both high and low annual rainfall areas, and at any time of year (Jonathan et. al., 2014). The consequence of this is felt on agriculture leading to fall in food production, crop failure, national economy, rise of unemployment, land degradation, desertification, loss of biodiversity etc. According to Yelwa and Eniolorunda (2012), the cumulative effect of drought is felt in other disasters such as desertification and famine; prominent in the Sahara and Sub-Sahara Africa.

Changing temperatures and precipitation, particularly when they occur quickly or in extremes, have a direct and often divergent effect on plant growth and hence, can impact the direction of competition among species (Friedlingstein*et al.,* 2022). Because the degree of climatic change is unlikely to be uniform over the world, the responses of plant populations in both regions to these changes are likely to differ. For example, General Circulation Models (GCMs) forecast warmer winter temperatures (than summer), notably in northern latitudes, but less precipitation and more drought regimes in some locations (IPCC, 2007). Plants respond in general positively to these change such as increasing growth and population size, and or negatively (decreasing growth with likely local extinctions) or by dispersal to new, more favourable sites. Thus two plant processes, phenology and range shifting, are important aspects in a plant’s response to climate change. But the crux of this study is on phenology as recorded by satellite remote sensing (Seile*et al.* 2022). Phenology is the timing of events in a plant's annual cycle, and it's often a response to changes in temperature, moisture, and light levels throughout the year, signaling stress. Leaf emergence, flowering, and leaf drop are examples of phenological occurrences that are easily observed (Liu *et.al.,* 2021). This is measured by satellite sensors as chlorophyll richness, which is a sign of plant health (Liu *et.al.,* 2022). With the introduction of satellite remote sensing, it is now able to analyze plant health and identify how precipitation, temperature, evaporation, relative humidity, and other factors have influenced plant health. These factors are driven by climate change and their cumulative effects are seen on vegetation health, plants yield and indeed food availability to both humans and animals.

## 2. LOCATION AND GEOGRAPHICAL SETTING

Kaduna statelies between $9^{o}02'$ and $11^{o}32'$ north latitude and $6^{o}15'$ and $8^{o}50'$ east of great circle of the prime meridian. Katsina, Zamfara, and Kano states border Kaduna to the north; Niger state to the west; Bauchi to the east; and Plateau, Nassarawa, and also the Federal Capital Territory, Abuja, to the south (Figure 1). The state covers roughly 43,460 sq. kilometers, creating it the most important within the northwest politics zone and accounting for regarding 4.7% of Nigeria' total acreage (Audu I.Aand Adie, 2018), (Laah, 2003). From north to south, the largest distance by road is around 290 square kilometers, and from east to west, it' regarding 286 sq. kilometers (Audu I.A and Adie, 2018). Its 3 major cities: Kaduna, Zaria, and Kafanchan, all of that are connected by varied sorts of highways, railway lines, and airports. The state of Kaduna features a big selection of natural environments. From the Kudaru ring advanced hills within the east to the large vale plains of the stream Kaduna in the west, the topography changes. The earth science of the realm is dominated by basement Precambrian rocks. Rolling lowland plains, often below 610 meters on top of ocean level, structure the landscape. this is often not unrelated to the extended baring of the basement advanced rocks that lay beneath the area. The realm is formed of varied compositions of associate degreecient granites, schist, and quartzite. The bottom increasingly dips all the way down to the west and southwest and is drained by 2 major rivers, the Kaduna and also the Gurara(NPC, 2006).

The study area is assessed as an Aw kind of Kopen' categorization theme (Pius, 2021), with two distinct seasons, a time of year in summer and a time of year in winter. The area is influenced by two distinct air masses that have a major impact on the climate. Between Nov and March, the northeast trade winds, that are usually dry and dusty, are notably strong air current. The moisture-laden tropical maritime airmass originates within the Atlantic is the second kind (Audu and Adie, 2018). The volatility of the border between these 2 air masses is because of the variations in the starting of rainfall.

The southern half of the state receives a lot of rain, averaging 500 mm per month between April and September (www.wikiafrica / africigeria / kaduna / physical / climate, 2016). The far north receives 146mm of rain each month, while the Kaduna metro receives 361mm. The temperature varies according to the season. The maximum temperature of $31^{o}C$ is frequently recorded in April, while the minimum temperature ($16^{o}C$) is usually reported during the harmattan season, which is between December and January. However, heavy evaporation during the dry season causes a problem of water scarcity, especially in the local government areas of Igabi, Giwa, Soba, Makarfi, Ikara and Zaria (www.wikiafrica / africanigeria / kaduna / physical / climate, 2016). The vegetation  is generally leafy and woody. Isoberline, doka, bridelis, terminalia, acacia, vitrex, and other tree species are common. The androgen family is the most common family of herbs and shrubs found  in bunches. Ferruginous tropical soils abound in most of the territory of Kaduna state.Due to heavy leaching, most soils contain 3040% clay at moderate depth. Mountain soils are rich in red clay and sand but lack organic matter. Due to the combined impacts of the two, the plains of Kaduna State have undergone notable changes over the years.

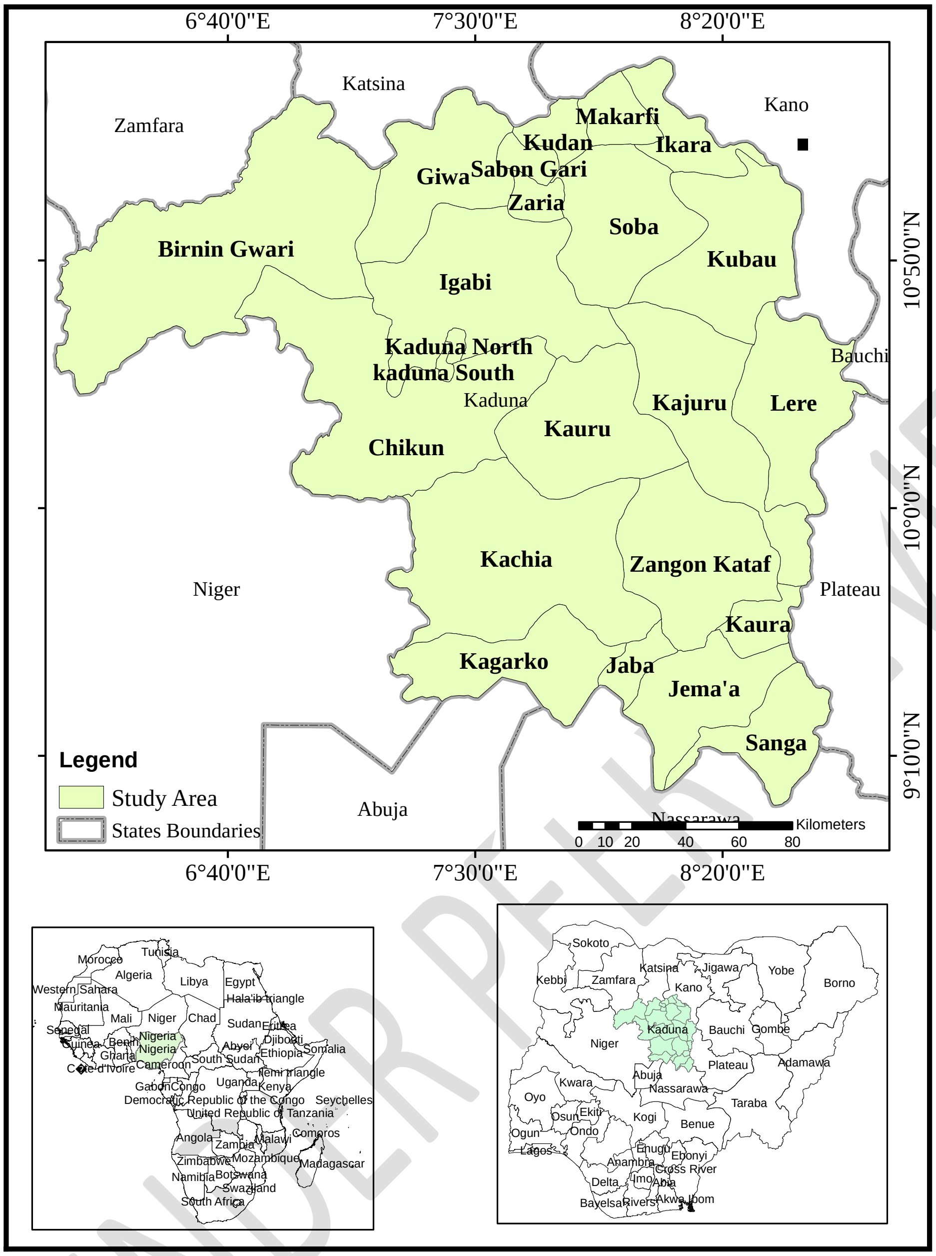


**Figure 1: Map of the study area covering all the LGAs** adopted and modified from Ministry of Lands and Survey, Kaduna State.

## 3. MATERIALS AND METHODS

The research made use of the Software for the Processing and Interpretation of Remotely Sensed Image Time Series (SPIRITS) developed by European Union (EU) Commission Vision on Technology (VITO) for the Food Security unit of the Joint Research Centre. It is a software environment for analyzing satellite derived image time series for crop and vegetation monitoring in an integrated and flexible analysis environment and with a user-friendly graphical interface. The software enables one to examine time series of low and medium resolution sensors. It can be used to perform and to automatize many spatial and temporal processing steps on time series and to extract spatially aggregated statistics. Vegetation indices and their anomalies can be rapidly mapped and statistics can be plotted in seasonal graphs to be shared with analysts and decision makers.



**Figure 2: Flow Chart of Research Method**

Vegetation anomalies is concerned with the identification and mapping of vegetation changes that do not correspond to certain times or periods of interest as induced by drought and climate and the overall impact on food security. Drought anomalies evaluation involves the creation of vegetation anomaly maps which is based on the comparison of actual NDVI and Rainfall Estimates (RFE) maps with the historical year. In the calculation of anomalies, the current dekad (or month or season) is compared to the long term average (LTA) of vegetation in the study area. This was carried out using the anomalies menu in the spirits software. However, the anomalies calculation was computed in two different important levels; the absolute difference and standardized difference. The absolute difference is calculated as: $ADVI_{y,p} = X_{y,p}$– mean p, with y = the year, and p = the period in the year (dekad) and ADVI = Absolute Difference Vegetation Index. The standardized difference gives an idea of how exceptional the vegetation status anomaly is, compared to the historical time series. The standardized difference is calculated as: SDVIy,p = (Xy,p – meanp) / stdevp, with y = the year, and p = the period in the year (dekad). The Standardized Difference Vegetation Index is thus the difference in terms of standard deviations from the mean situation for that particular dekad, and for each pixel, or also called the z-score.The vegetation anomalies were calculated in two different dimensions; the absolute difference, and standardized vegetation changes. These quantify different levels of changes in the vegetation dynamics within the period under review. The maps so generated represent these changes.

## 4. RESULTS AND DISCUSSION

### Absolute Differences

The absolute difference is calculated as: ADVIy,p = Xy,p – meanp, with ADVI=Absolute Difference Vegetation Index, y = the year, and p = the period in the year (dekad). The results of the analyses are presented in Appendix 1. The result is an array of images of decadal changes. These are the outright changes in vegetation from January 2003 to December 2018. The first two numbers of each of the image is the year which starts from 03 to 18 while the last two numbers represent the dekad which starts from 01 to 36 indicating the number of dekads in each year. A dekad comprise of ten (10) days; given rise to 3 dekads in a month and 36 in a year. Therefore, absolute difference changes images returned 576 images which is very sufficient to monitor and detect any changes in the vegetation be it increase or decrease.

Taking a cursory look at the images (Appendix 1), it is clear to see that the vegetation increases across dekads in a random manner without any consistent order. It is expected that there should be a consistent pattern of vegetation change across the years in accordance to the rainfall pattern. Thus, it is expected that there should be greener from May to November in most parts of the study area and from July to October in the furthest north. Thus; for the year 2003, the greatest changes were observed from the $15^{th}$ dekad (i.e. the last dekad in May) to the $18^{th}$ dekad (i.e. the last dekad of June). From this point onward, there was very little changes in the vegetation. This was expected to happen in 2004; but 2004 had a different time of change. 2004 recorded its greatest change from the $3^{rd}$ (i.e. end of January) up to $10^{th}$ dekad which is the first dekad of April. This is a bit earlier than 2003. Again 2004 recorded another episode of change from the $28^{th}$ dekad continuously to the end of the where 2005 continued until the $11^{th}$ dekad. 2005 recorded another change from $31^{st}$ dekad to the end of the of the year with a gradual decrease in change. 2006 appeared to have experienced very little changes until the last the last the dekad (i.e. between 21 to 31 of December). This change continued in 2007 until the $11^{th}$ dekad where it diminished greatly. The change picked up again from the $29^{th}$ dekad where it continued into 2008 till the $15^{th}$ dekad where it break and continued from the $26^{th}$ dekad down to the end of the year in decreasing manner.

The year 2009 recorded its significant difference from the $5^{th}$ dekad (Mid February) to the $11^{th}$ dekad (Mid April) where it seized completely. 2010 and 2011 recorded very few absolute differences which occurred from $7^{th}$ to $13^{th}$ dekad and the $1^{st}$ to the 13 dekad, continued from $28^{th}$ to the $36^{th}$ dekad respectively. 2012 recorded highest change from the $1^{st}$ dekad to the $16^{th}$ then seized and continued on the 35th and 36 dekads. From the first dekad to the 6th dekad, 2013 recorded its absolute change in vegetation and 31st to 36th. In 2014 only recorded changes in the 34th to the 36th dekad. From the previous year, 2015 continued down to 20th dekad where it seized and continued from the 35th into the 8th dekad of 2016 where it showed some isolated changes and picked up again from the 29th dekad down to 17th dekad of 2017. After 10 days, there was recorded another change from 27th dekad of 2017 down to 19 dekad of 2018 and 35th and 36th dekads which marked the last in the time series.

The absolute difference change images show a random pattern of occurrence which in most occasions does not align with changes with regards to any of the indices under review. However, these changes are indicative of the situations in vegetation anomalies which could be a result of several climatic factors. Any climatic variable could single handedly or in association with other factors trigger these changes. However, the response most not be in tune with any of such variables. Most important is that these changes have been observed and monitored and this information so derived is used in predicting and providing early warning signals to crop failure, drought onset and its dynamics.

**Standardized Differences**

More interesting than the absolute differences is the standardized difference which gives an idea of how exceptional the vegetation status anomaly is, compared to the historical time series. The standardized difference is calculated as: $SDVI_{y,p} = (X_{y,p} – mean_p) / stdev_p$, with y = the year, and p = the period in the year (dekad). The Standardized Difference Vegetation Index is thus the difference in terms of standard deviations from the mean situation for that particular dekad, and for each pixel, or also called the z-score. The SVI is based on calculation of a z score for each eMODIS pixel location in the study area. The z score is a deviation from the mean in units of the standard deviation, calculated from the NDVI values for each pixel location for each week for each year.

This SDVI is a per-pixel probability, expressed as the Standardized Vegetation Index (SDVI), is an estimate of the "probability of occurrence" of a particular vegetation condition. The values of the SDVI range between greater than zero to less than one ($0 < SDVI < 1$). Zero is the baseline condition in which a pixel NDVI value is lower than all possible NDVI values for that time in other years. One is the baseline condition in which the pixel NDVI value for the respective Time is higher than all the NDVI values of the same week in the other years.

The purpose for the computing is to show how the SDVI can be a valuable tool when used in conjunction with the NDVI maps. In some cases, there is not a clear match between the two products. This can happen for several reasons: (1) because the SDVI reflects short-term vegetative response to weather conditions and the NDVI maps show both short term and longer-term drought conditions, (2) the SDVI map will show areas of relatively good or poor vegetation status and will show changes more quickly than the NDVI maps; (3) relatively poor vegetation conditions may be caused by other factors besides drought (e.g., flooding, unseasonable coolness that can put vegetation behind phenologically, or crop rotation); and (4) the NDVI maps are a mix of objective and subjective determinations of drought conditions and may not be in themselves completely accurate.

Appendix 2 displays the time series images of the SDVI. It is clear that almost all the images had some degree of observed changes; there are specific times that differences are more pronounced than others. This however, does not show any pattern or trend. For the year 2003, standardized difference showed very good changes from the $1^{st}$ to the 13 dekad. This growth in vegetation was confined to the northern part of the state. Conversely, the southern part of the state recorded a very poor change from the $16^{th}$ to $19^{th}$ dekad. Again from the $31^{st}$ dekad, there were random pockets of very high change across the entire state with a little concentration in the mid region. This continued nonstop to the fourth dekad of 2004 where it changed direction to the far north and gradually faded. Between the $13^{th}$ and $15^{th}$ dekads of 2004, while the northern part of the state was witnessing a high change signifying a growth in vegetation, the southern state recorded very little growth. From this point again, high changes were recorded largely in the northern part where it scattered across the state and faded gradually leaving the medium change to dominate over 90% of the entire state. In 2005, only the northern part of the state recorded high change in vegetation which stated from $13^{th}$ to $18^{th}$ dekad that is from the first week of May to the June. This was followed by pockets of low changes scattered across the state but medium change dominated the entire year.

From the $1^{st}$ to the $7^{th}$ dekad of 2006, there was high change across the entire state. This gave way to medium change and pockets of low changes in random manner. In 2007, the horn of Kaduna (largely Birnin Gwari) recorded low changes from the first to $5^{th}$ dekad. In the same year, the northern part of the state recorded high change from the $10^{th}$ dekad which spread across the entire state to the 17 dekad where it faded into the medium change. It gave way to random pockets of low change across the state with more concentration in the north from $27^{th}$ dekad up to the $32^{nd}$ dekad where it wane out. The year 2008 started with interchangeable pockets of low and high changes which were witnessed in many parts of the state without any particular order of occurrence. 2009 recorded very high changes in the first 5 dekads of the year after which it became very irregular till the $31^{st}$ dekad when it became consistent to the end of the year. This was interspersed with pockets of low change especially in southern part of the state. The high change recorded in the last dekads of 2009 continued into 2010 until the $7^{th}$ dekad where it wane out and shifted to the far north. This later gave way to low changes in the $19^{th}$ dekad until the $27^{th}$ dekad when high change was recorded again till the end of the year noticed in almost every part of the year.

2011 was stable year with no meaningful changes except for isolations of high changes which occurred randomly between the $1^{st}$ and $9^{th}$ dekads. 2012 however recorded the opposite of 2012 i.e. low changes with few exceptions in the last 5 (November and December) dekads which recorded significant high changes. These were witnessed in all parts of the state with minor concentrations in the western half of the state. 2013 started with pockets of high changes in eastern half of the state until the $5^{th}$ dekad where it spread across the entire state till the 14 dekad. This was interspersed with pockets of no changes scattered across the entire state within this period. In the first 19 dekads of 2014, there were scattered pockets of high changes which occurred randomly. This gave way to seemingly similar pockets of low changes i.e. in manner for the remaining part of the year but was occasioned with high vegetation in the south fringe of the state (Kaura, Sanga and Jema'a LGAs) in the last 6 dekads. 2015 started with the medium change which was truncated in the 13 dekad with low change in greater part of the northeastern part of the study until the $22^{nd}$ dekad. Between the $25^{th}$ and $33^{rd}$ dekads were pockets of high change interspersed the medium changes. 2016 started with small pockets of low changes until the 7th dekad where high change was observed in almost every part of the state until the 13 dekad. This gave way to another episode of low change scattered majorly within the central part of the state. This continued until the 18th dekad of 2017 where it showed high magnitude between the 9th and 12th dekad of 2017. This gave way to very few pockets of high change until the until the 29th dekad where low change was recorded again which transcended into 2018 in the 4th dekad. This give way to few pockets of high changes especially in the far south between the 7th and 12th dekad. During this same time, the north recorded low changes. This low changes were observed in almost all parts of the state until the 29th dekad where another episode of high changes were recorded which last till the end of the year.

**Pattern of Vegetation Dynamics**

The pattern of vegetation dynamics presents the pattern of change in vegetation. It is important to understand what has occurred; discern the areas of increase versus decrease, the areas of maximum change versus minimum change. This information is important in decision making regarding the type of crop that should be grown in what areas.

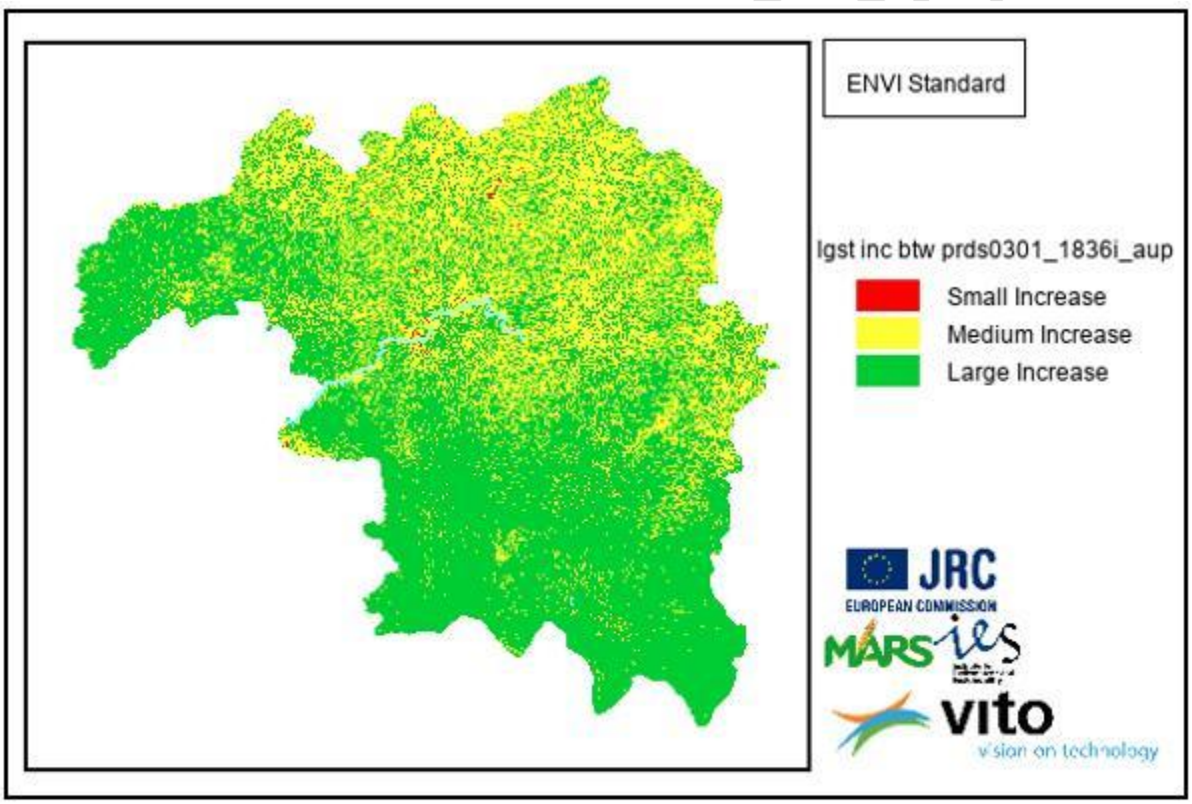


**Figure 3: Vegetation Increase between 2003 - 2018**

Figure 3represents the largest increase and largest decrease recorded in the entire study area within the period of the study. The largest increase is seen to have taken place in the southern part of the study area. This is so in view of the length of time because the analyses considers the entire length of time and records which regions witnessed the most significant increase over time. The medium decrease is observed in over 65% of the study area covering the central part of the state to the north.

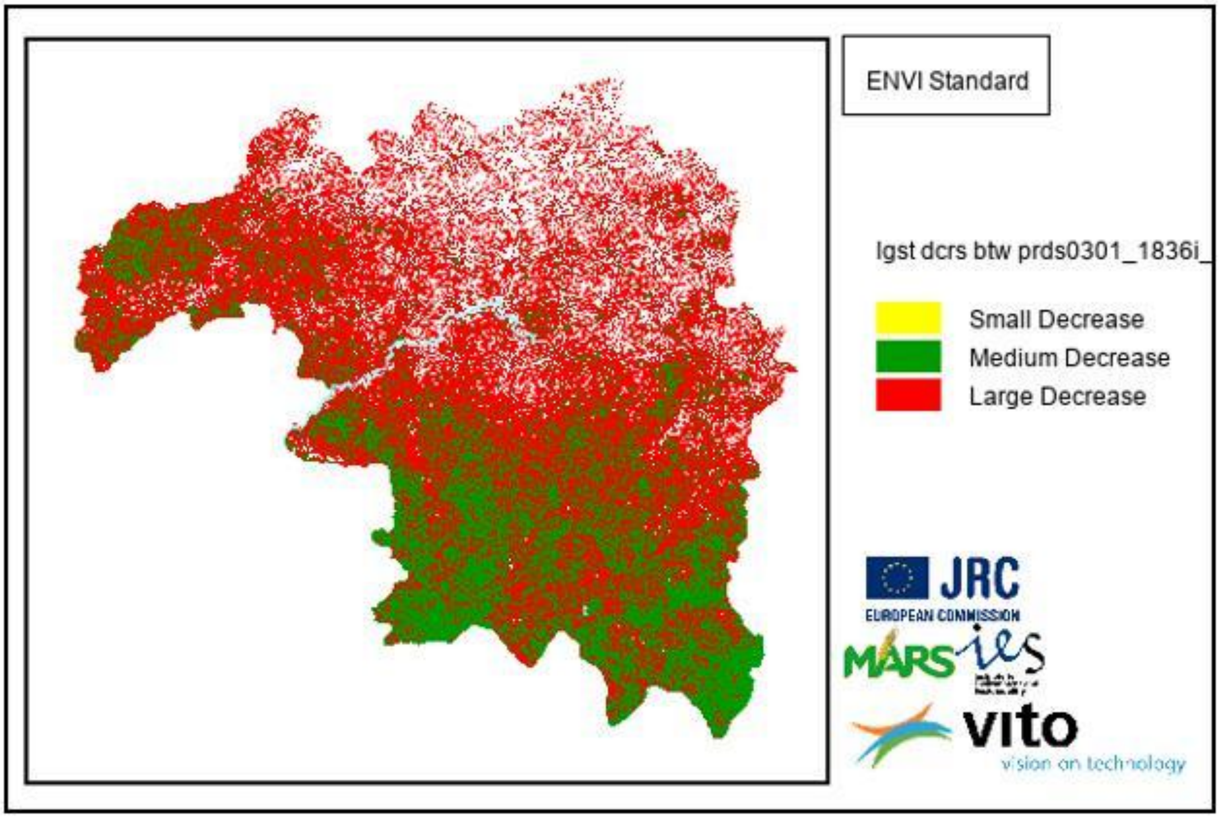


**Figure 4.: Vegetation Decrease 2003-2018**

The small increase is the smallest and very insignificant. These regions probably did not experience any increase at because they coincide with the major buildup areas i.e. Kaduna metropolis, Zaria and others. Conversely, Figure 4. represents the areas of largest decrease. It would be expected that the areas of small increase should coincide with areas of largest decrease. But this change is a random one meaning that it is not necessary that areas of large decrease to be areas of large increase. However, the large decrease coincides with the areas of medium increase in the preceding image but even extends beyond and covers about 75% of the entire state. Similarly, the area of medium decrease falls within the area of large increase in the preceding image but is much smaller.

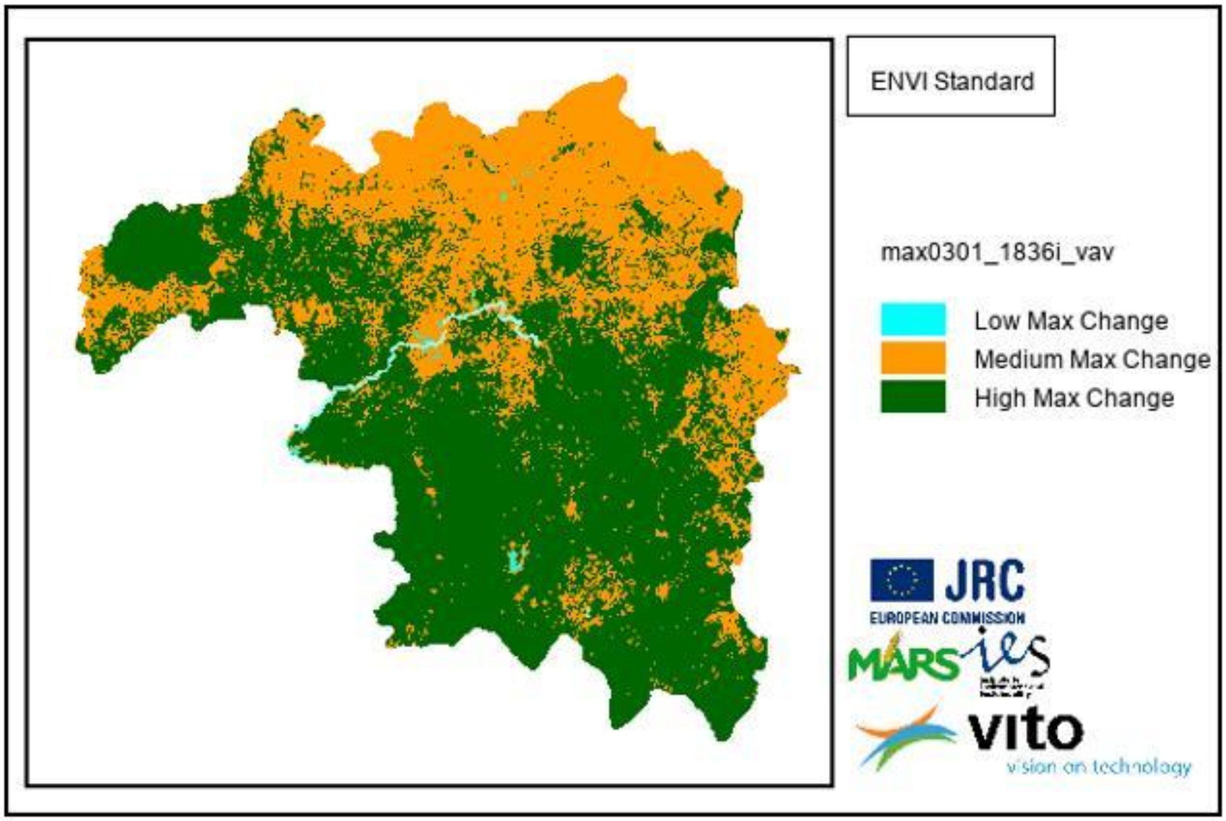


**Figure 5: Areas of Maximum Change**

The areas of maximum NDVI change are presented in Figure 5. The maximum NDVI was divided into three groups based on observed major changes and for the sake of quantification even though the entire image represents maximum NDVI for all parts of the state. Thus the greatest NDVI was recorded in the greater part of the southern part of the state stretching into the central area and terminates in the horn of the state. This covers about 53% of the entire state. The medium change which was witnessed in the northern part of the state and isolated pockets in the south and the horn of the state covered about 45% of the state. The small maximum group covered just about 2%. However this group comprise of water bodies and may be interpreted that as no NDVI at all.

Similarly, the areas of minimum NDVI (Figure 5) represent the areas that recorded the least amount of vegetation in all parts of the state. This was also divided into groups. This was more random that the maximum NDVI. The high minimum NDVI was recorded in small clusters and concentrated in the edges of southern part of the state. These areas coincide with rocky environment with barely any form of vegetation. Similarly, the implications of the changes recorded are enormous.

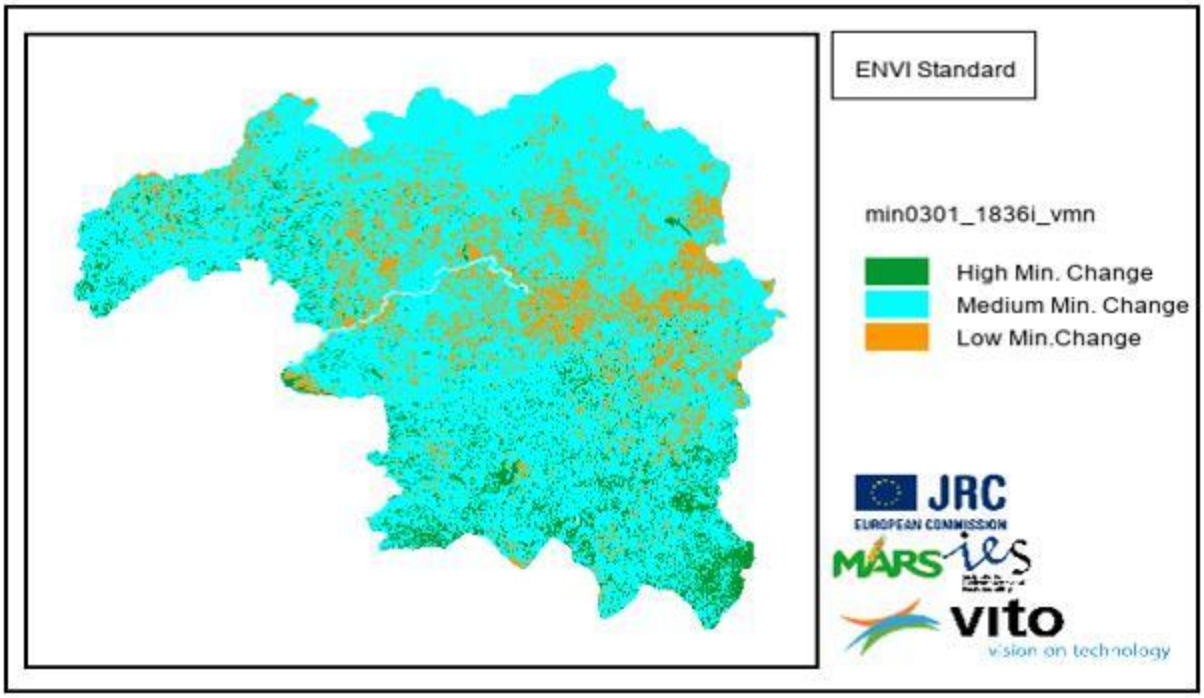


**Figure 6: Areas of Minimum NDVI**

Although the change may appear insignificant by virtue of their numerical values, their cumulative numerical (effects) values can greatly affect our food security especially with long duration and severity. If the high change should for instance occur in the entire state and continuously year in year out for the next 16 years, we would have lost more than half what we are producing now in terms of food. Although these anomalies occur within very short periods, they can greatly reduce crop yield by virtue of the stress crop encounter within this short periods of anomalies.

## 5. CONCLUSION

The vegetation anomaly was calculated in two different dimensions; the absolute difference, and standardized vegetation changes. These quantify different levels of changes in the vegetation dynamics within the period under review. The maps so generated represent these changes. However, to say whether the change is negative or positive is not important here. What happens here is that the satellite sensor records the present situation with respect to the previous. If at the present moment there is increase in vegetation as against the previous, the sensor will record it as increase. If tomorrow the vegetation decreases against what is recorded today, the sensor will record it as decrease. It is these momentary increase or decrease that we are interested in here. It is these changes that are grouped into low, medium and high changes. However, where the vegetation remains unchanged, this is designated as no change; and the no change was recorded only in a few occasions in the entire period under review. This indicates that the vegetation is continuously witnessing severe changes.The changes recorded in the study within the period under review where very random. The changes showed no particular pattern or trend.

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**Appendix 1: Absolute change difference images**


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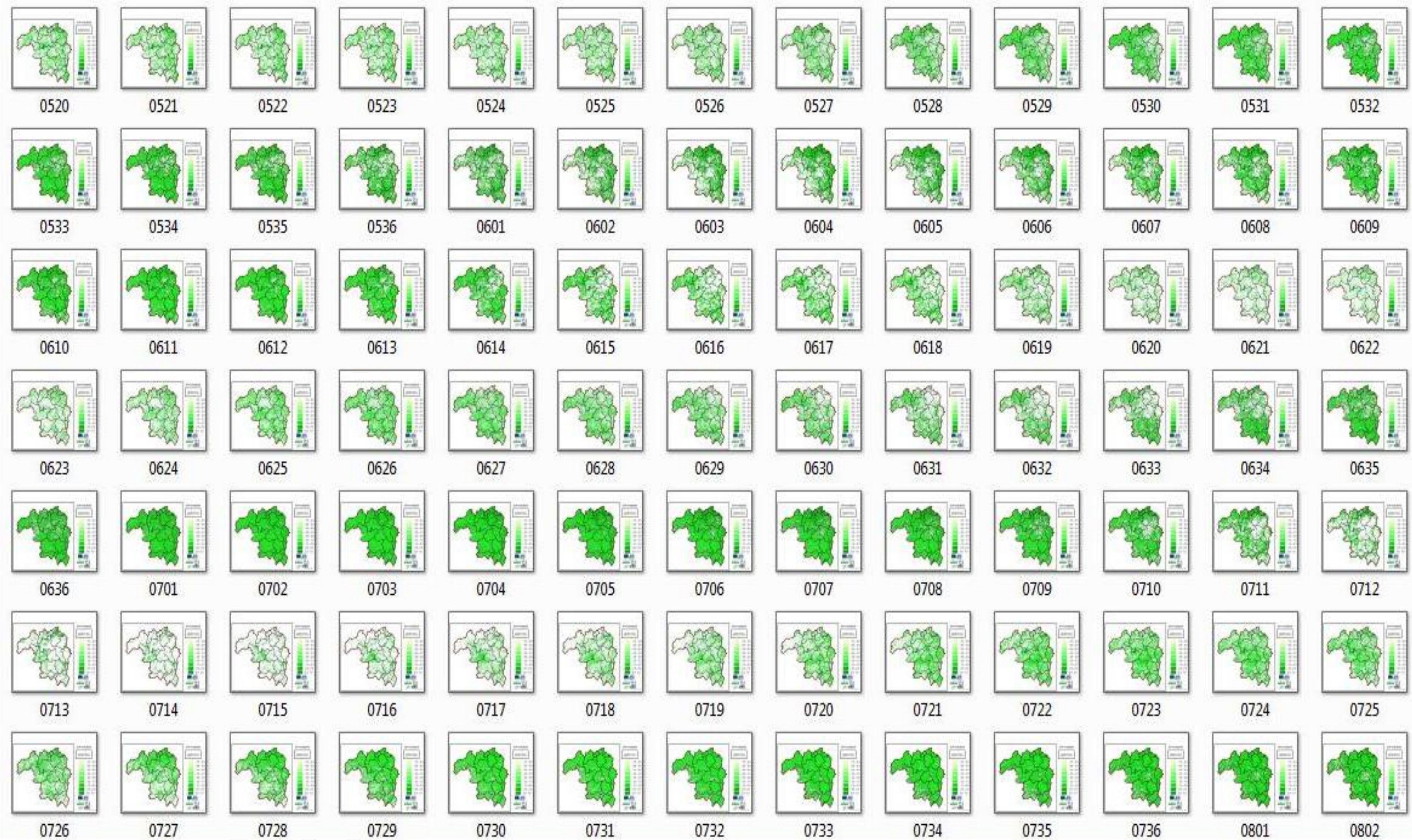
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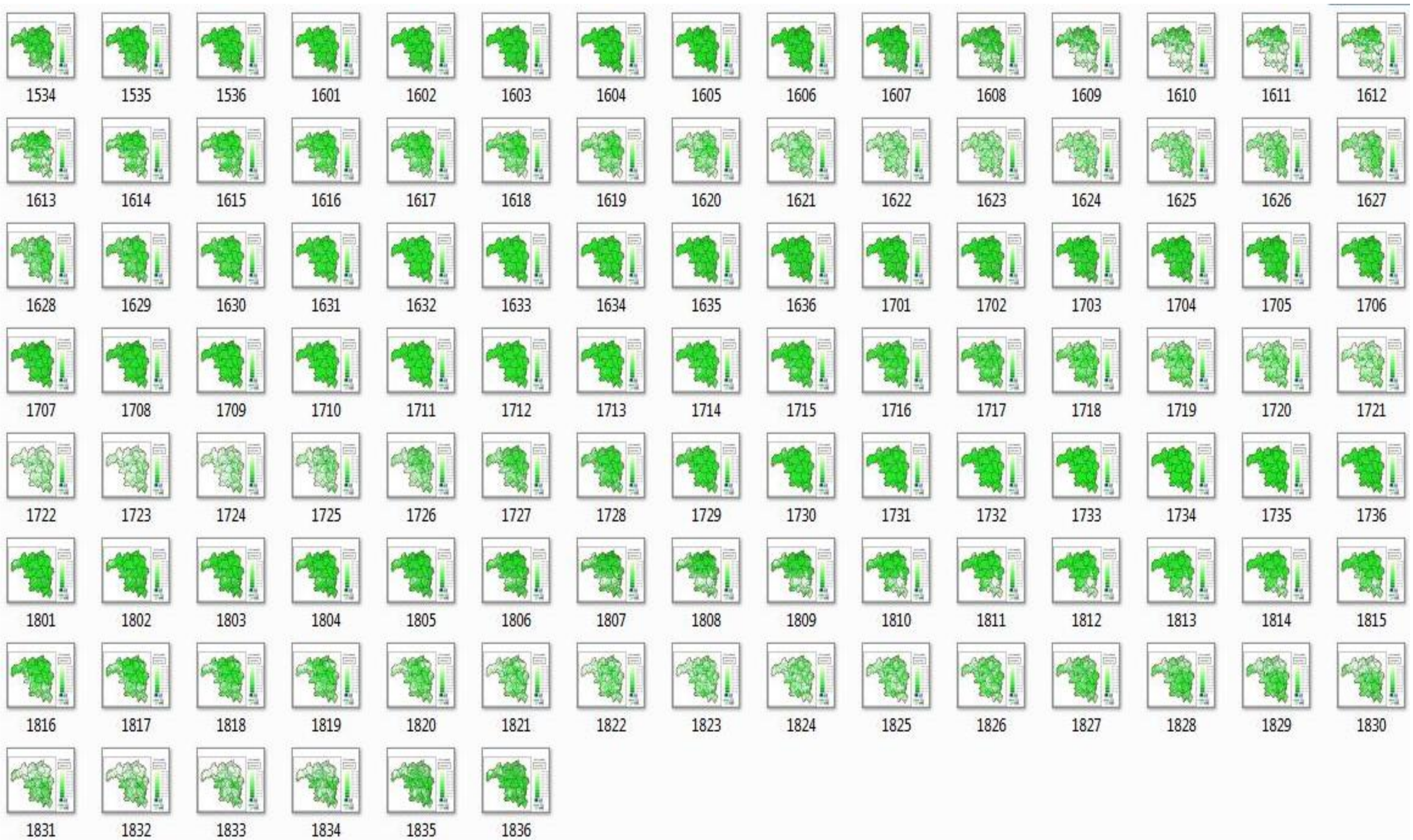
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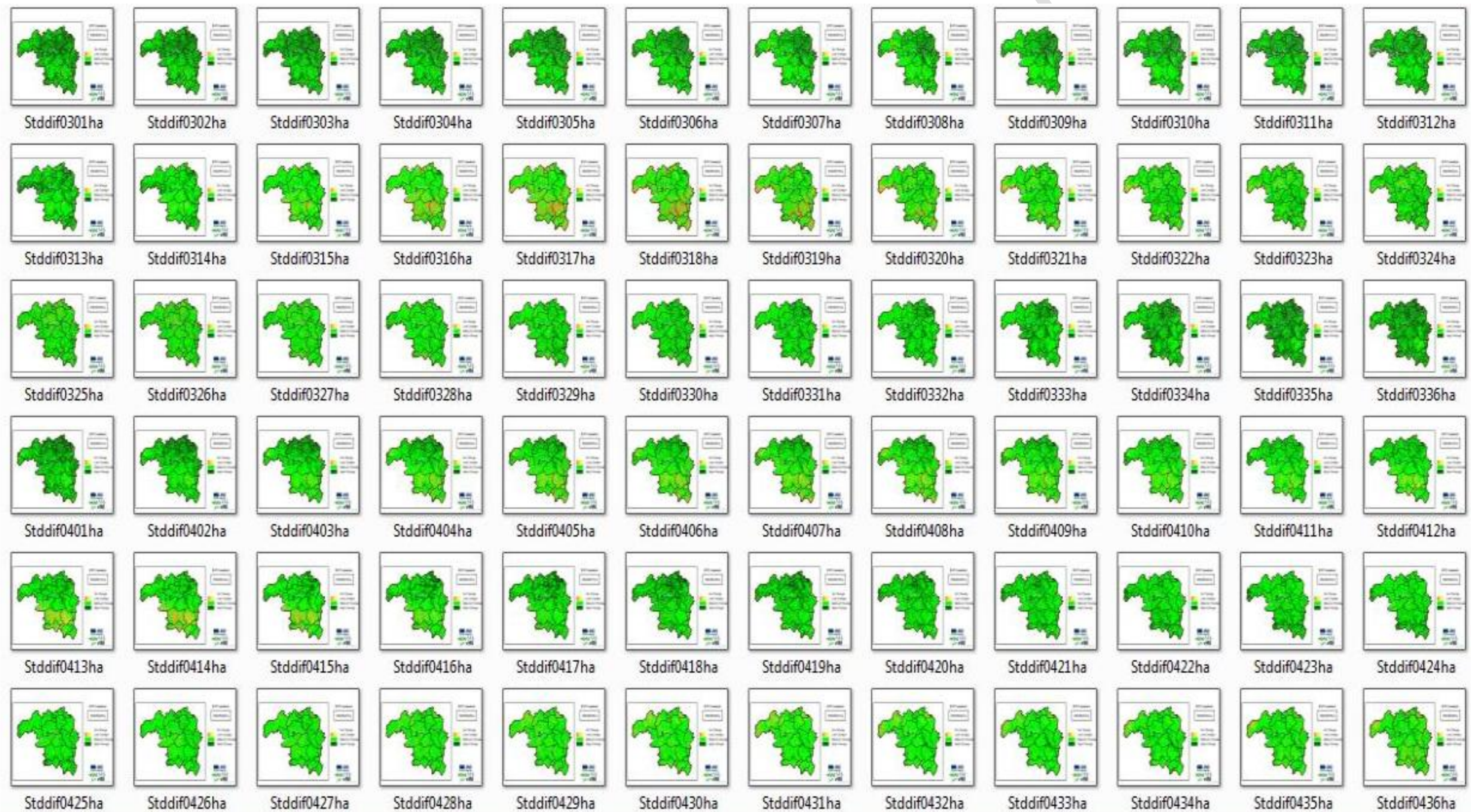
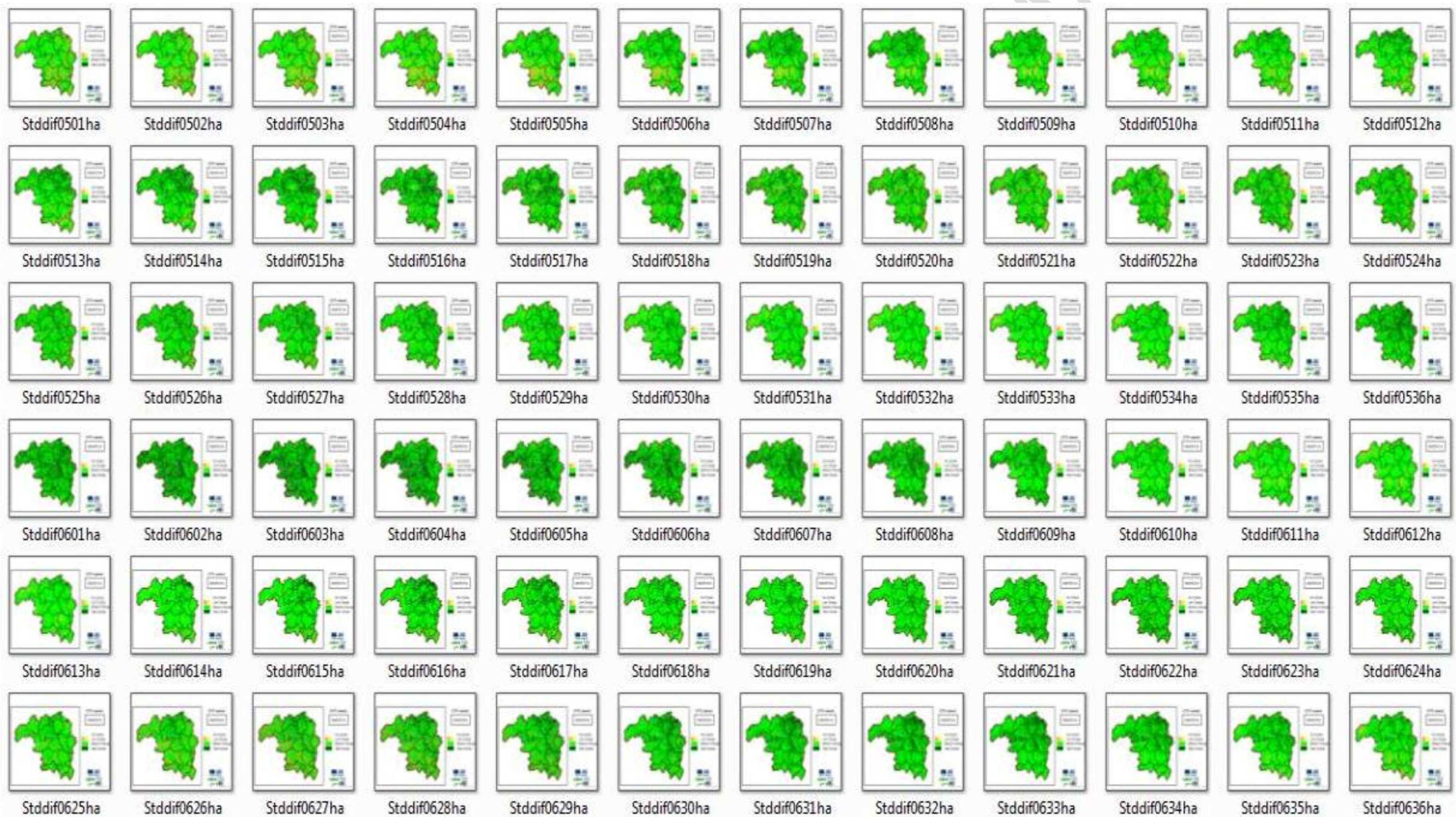
## Appendix 2: Standardized Difference Change Images

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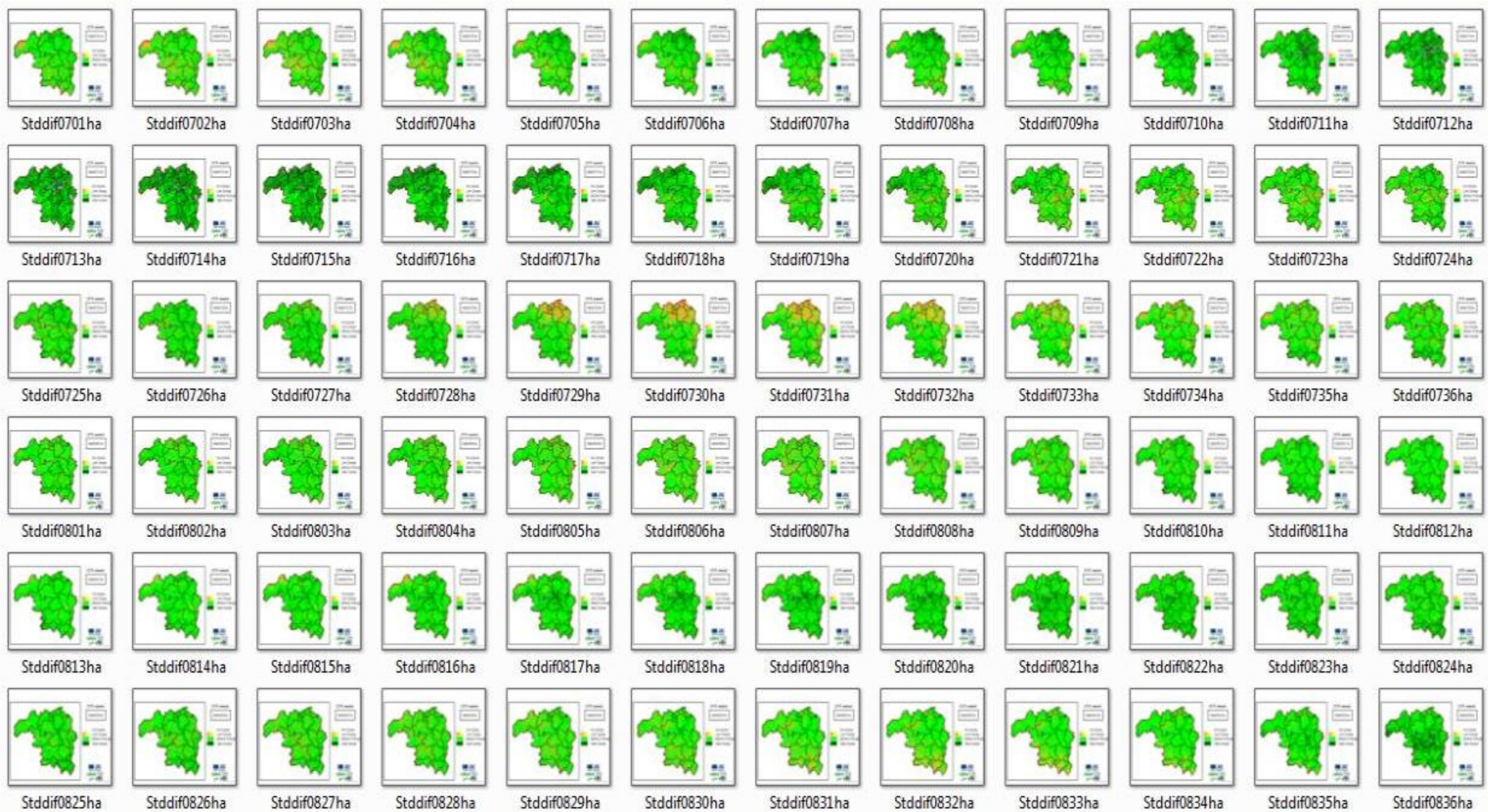
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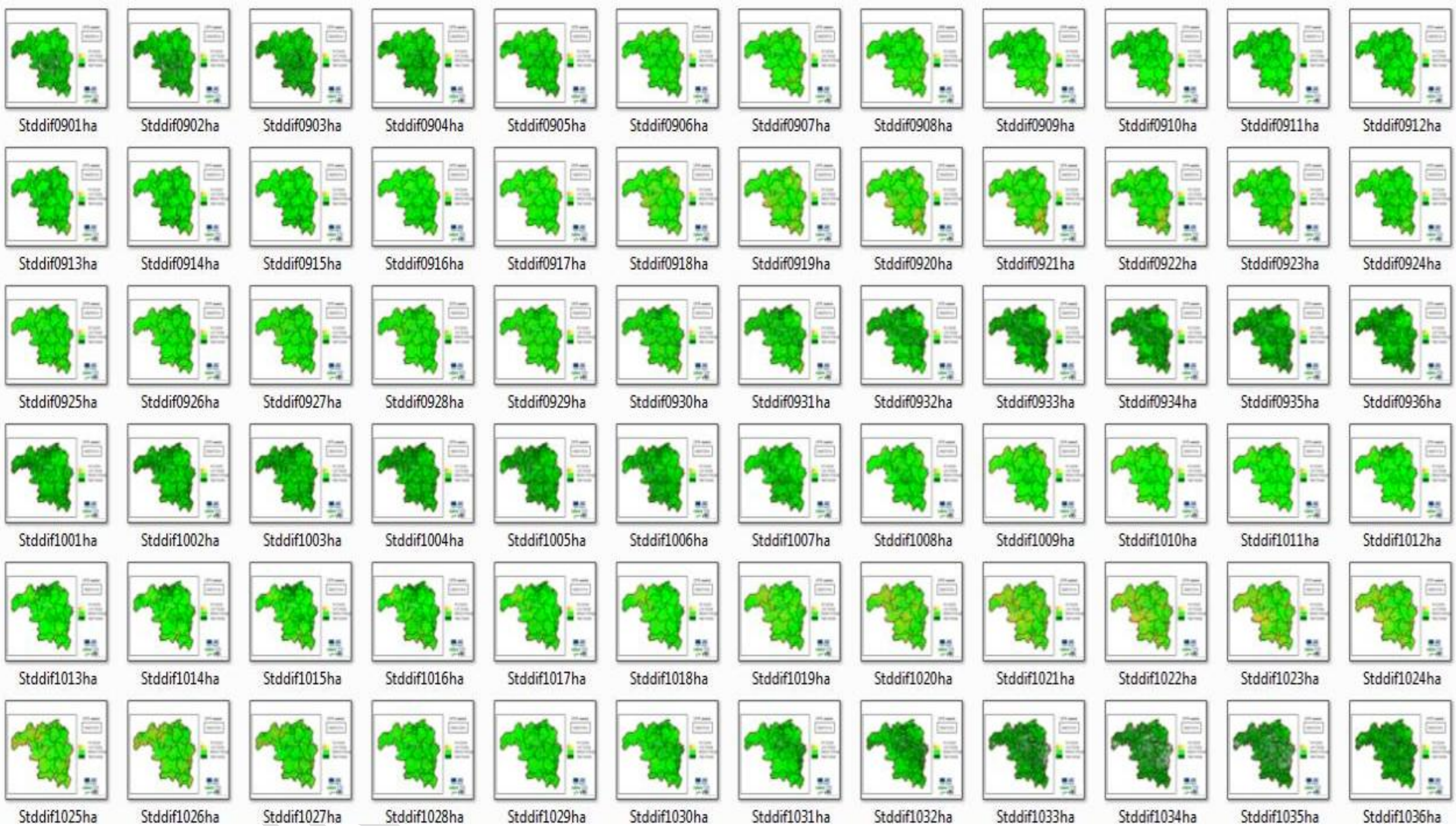
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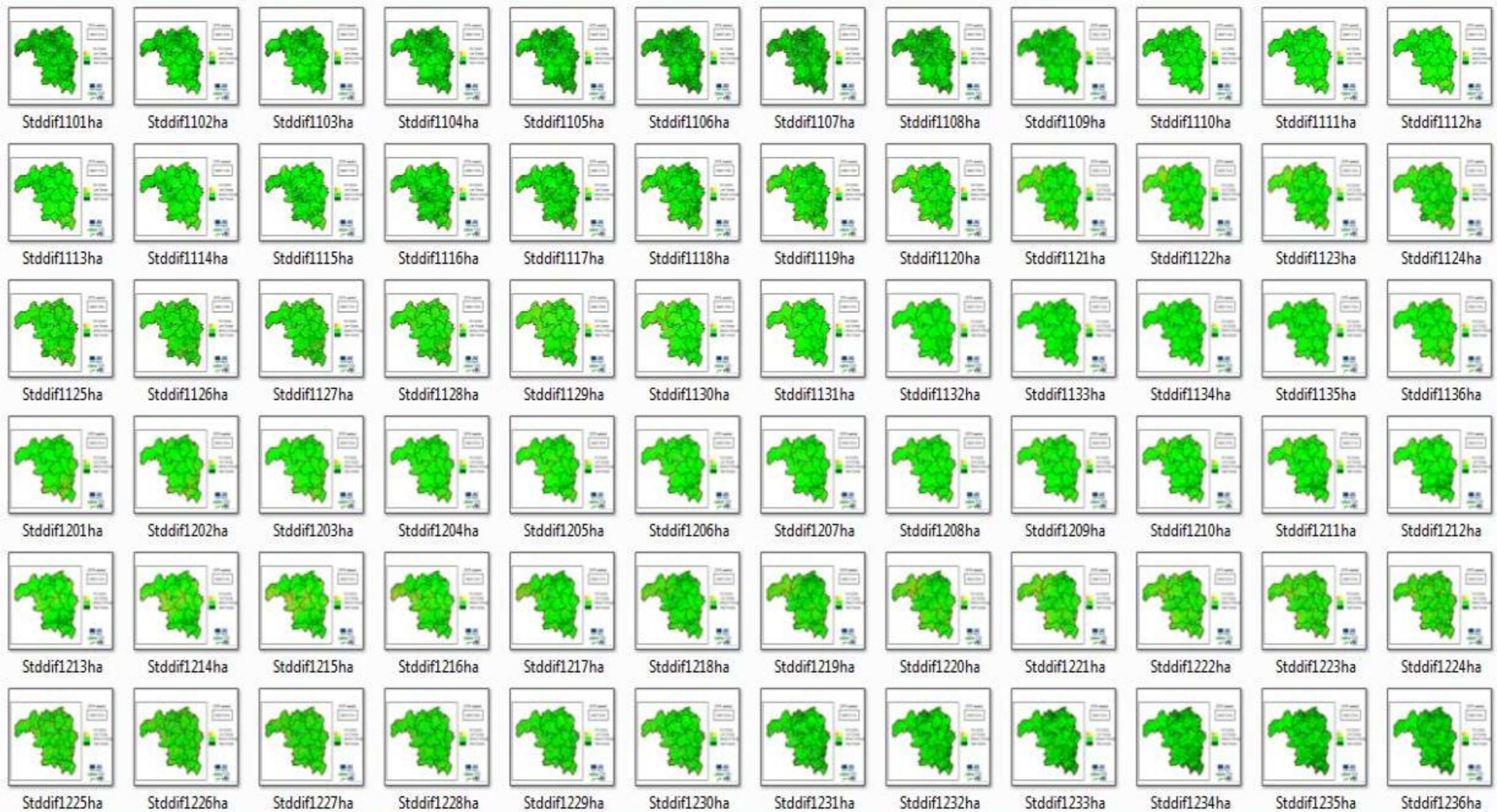
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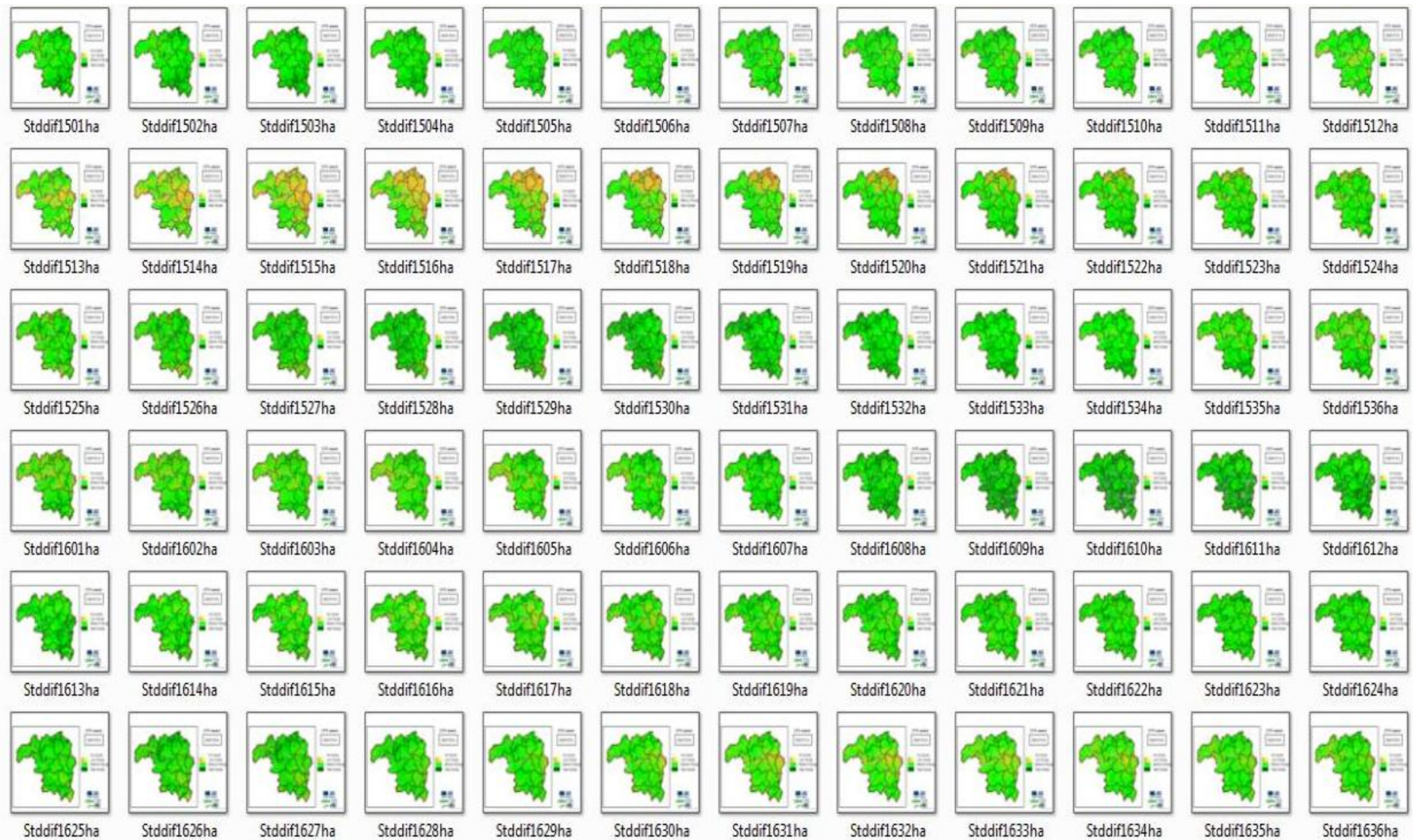
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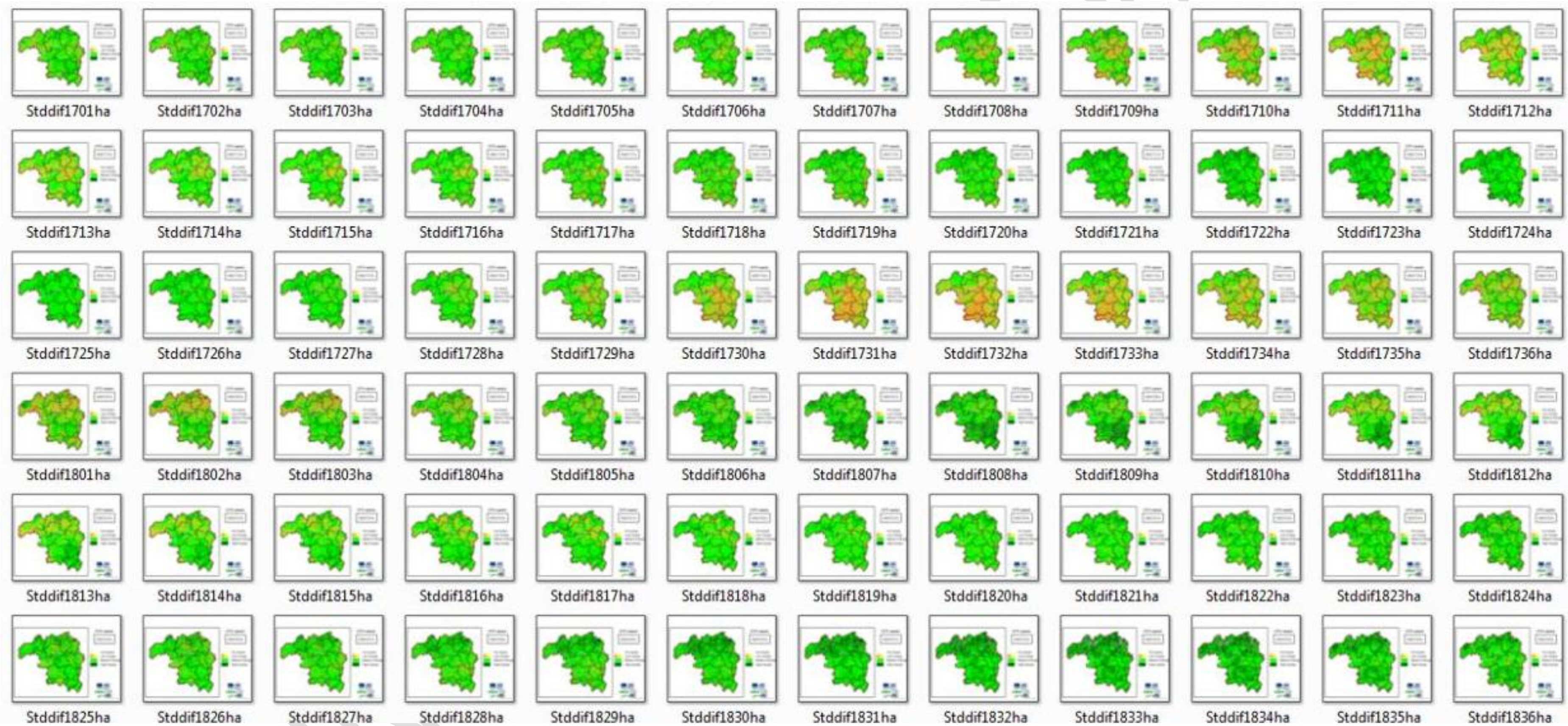
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