



FAO-Agriculture Stress Index System (ASIS)

Developed by:

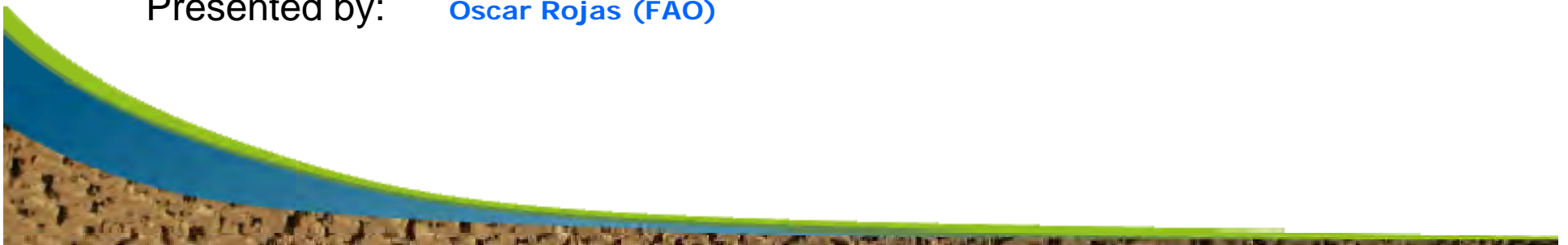


In collaboration with:



UNIVERSITY OF TWENTE

Presented by: **Oscar Rojas (FAO)**





Monitoring Agriculture Drought with Remote Sensing Data

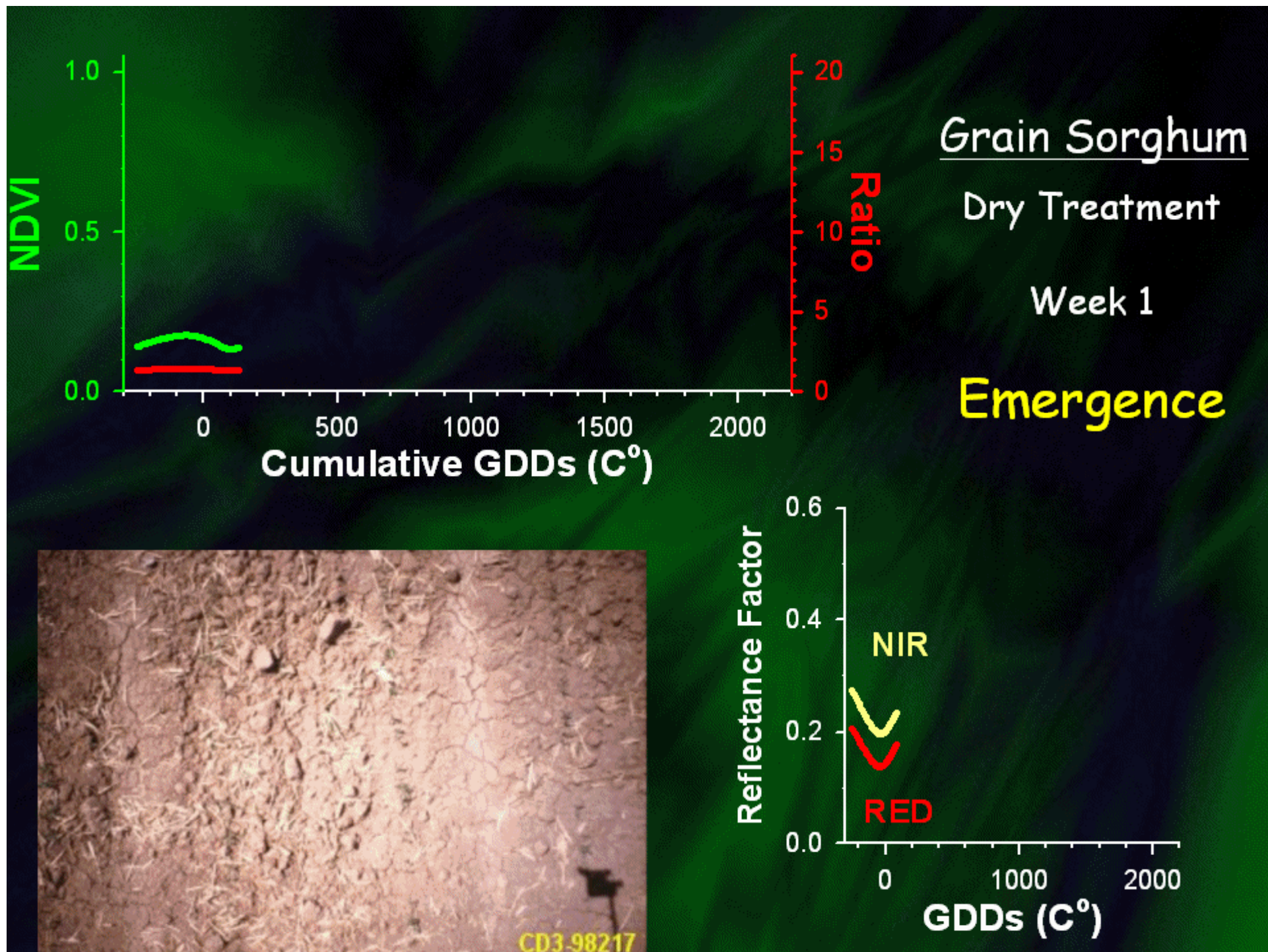


FAO's Global Information and Early Warning System (GIEWS) and the Climate, Energy and Tenure Division are developing a system for detecting agricultural areas with a high likelihood of water stress (drought) at global, regional or country level.



The **Agricultural Stress Index System (ASIS)** is based on 10-day (dekadal) satellite data of vegetation and land surface temperature from the METOP-AVHRR sensor at 1 km resolution.





Agricultural Stress Index System is based on the Vegetation Health Index (VHI) (Kogan et al. 1995)

Vegetation condition index (VCI)

$$VCI_i = \frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

Temperature condition index (TCI)

$$TCI_i = \frac{BT_{max} - BT_i}{BT_{max} - BT_{min}}$$

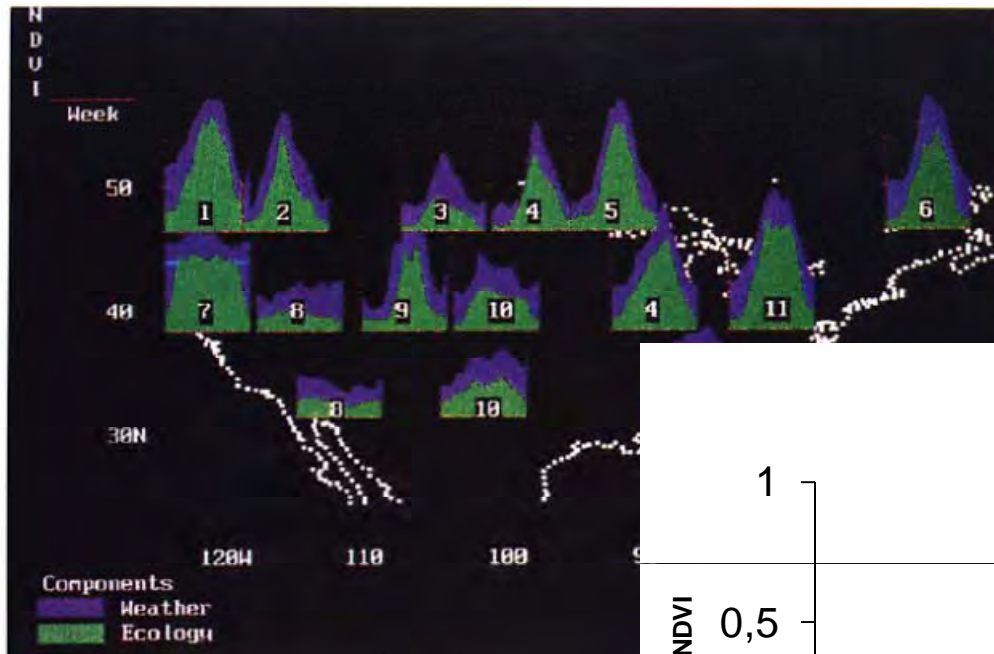
Vegetation Health Index (VHI)

low VHI

$$VHI = a \cdot VCI + (1-a) \cdot TCI$$

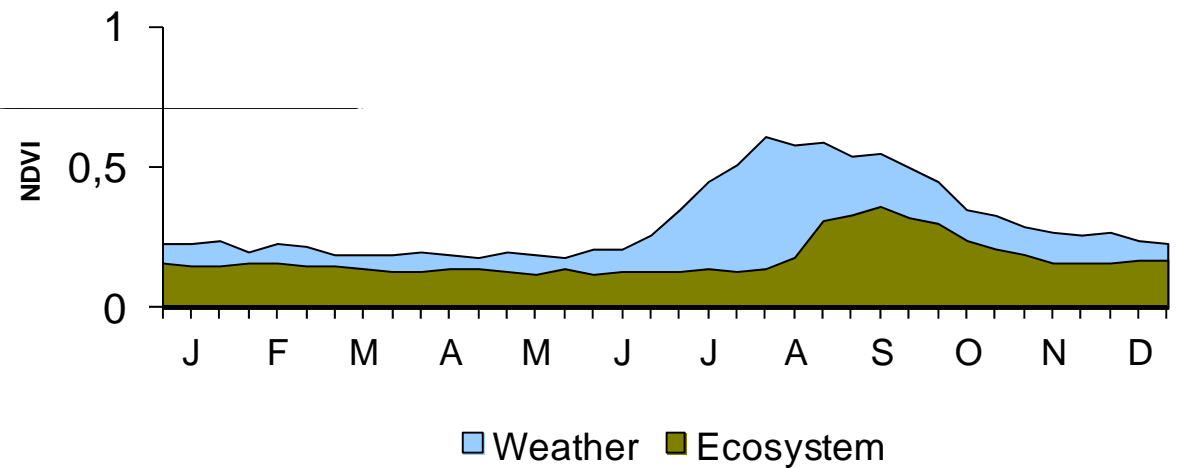
high VHI



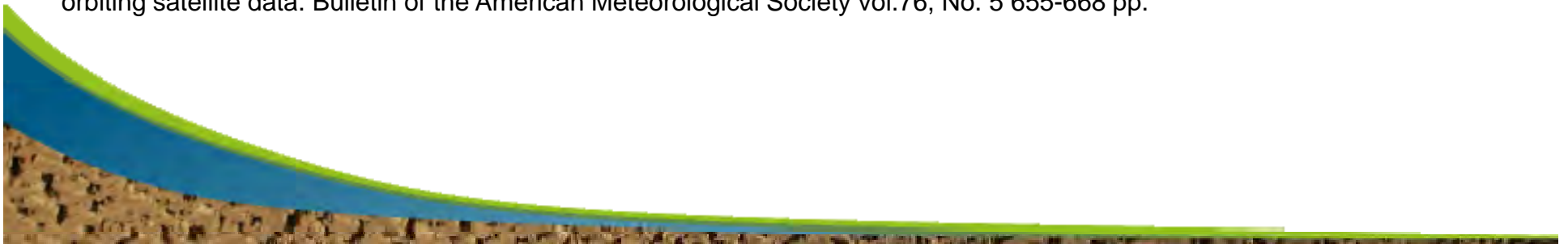


$$VCI_i = \frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

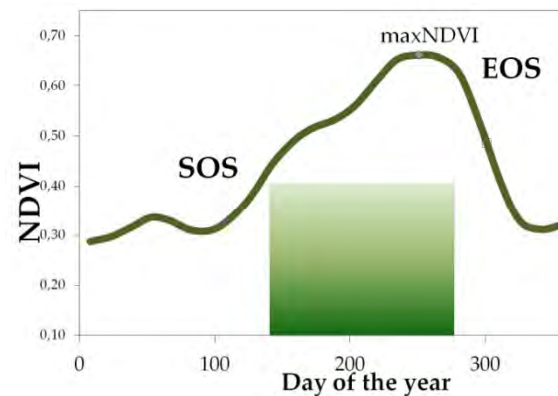
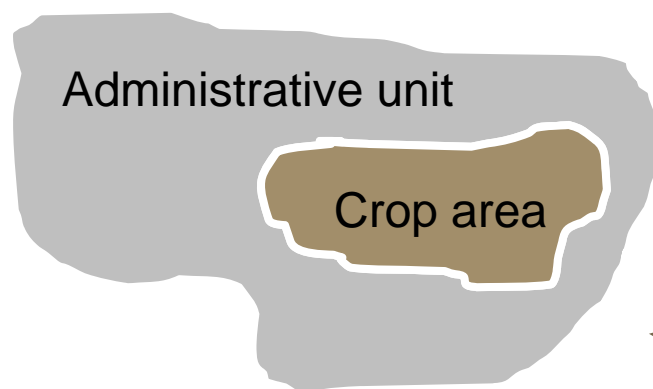
Hodh El Gharbi, Mauritania



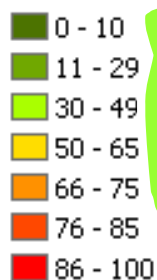
Source: Kogan, F. 1995. Droughts of the late 1980s in the United States as derived from NOAA polar-orbiting satellite data. Bulletin of the American Meteorological Society vol.76, No. 5 655-668 pp.



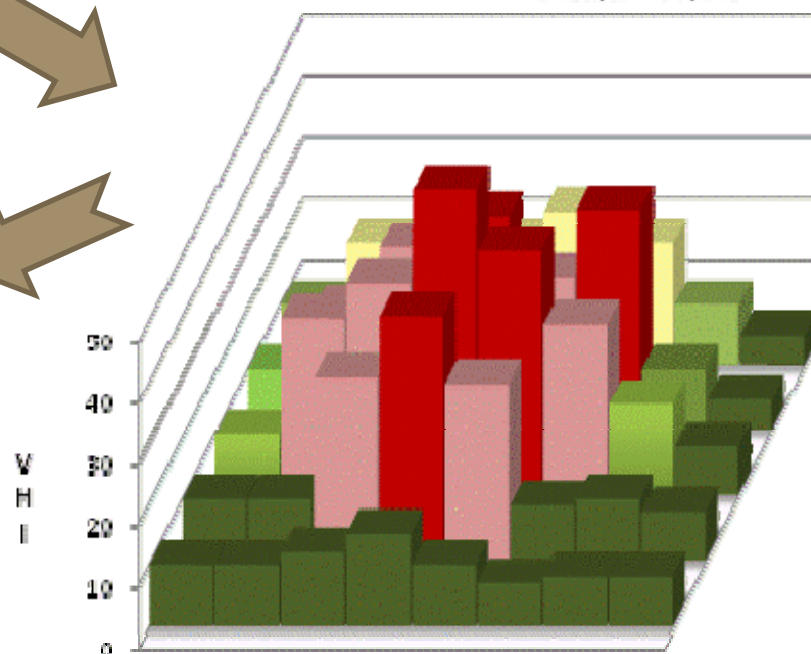
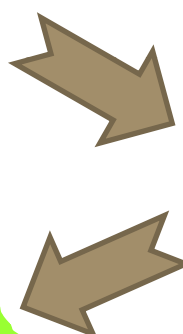
ASIS assess the severity (intensity, duration and spatial extent) of the agricultural drought



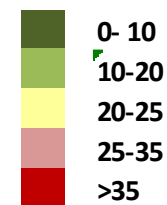
Percentage of the agriculture areas with VHI below 35



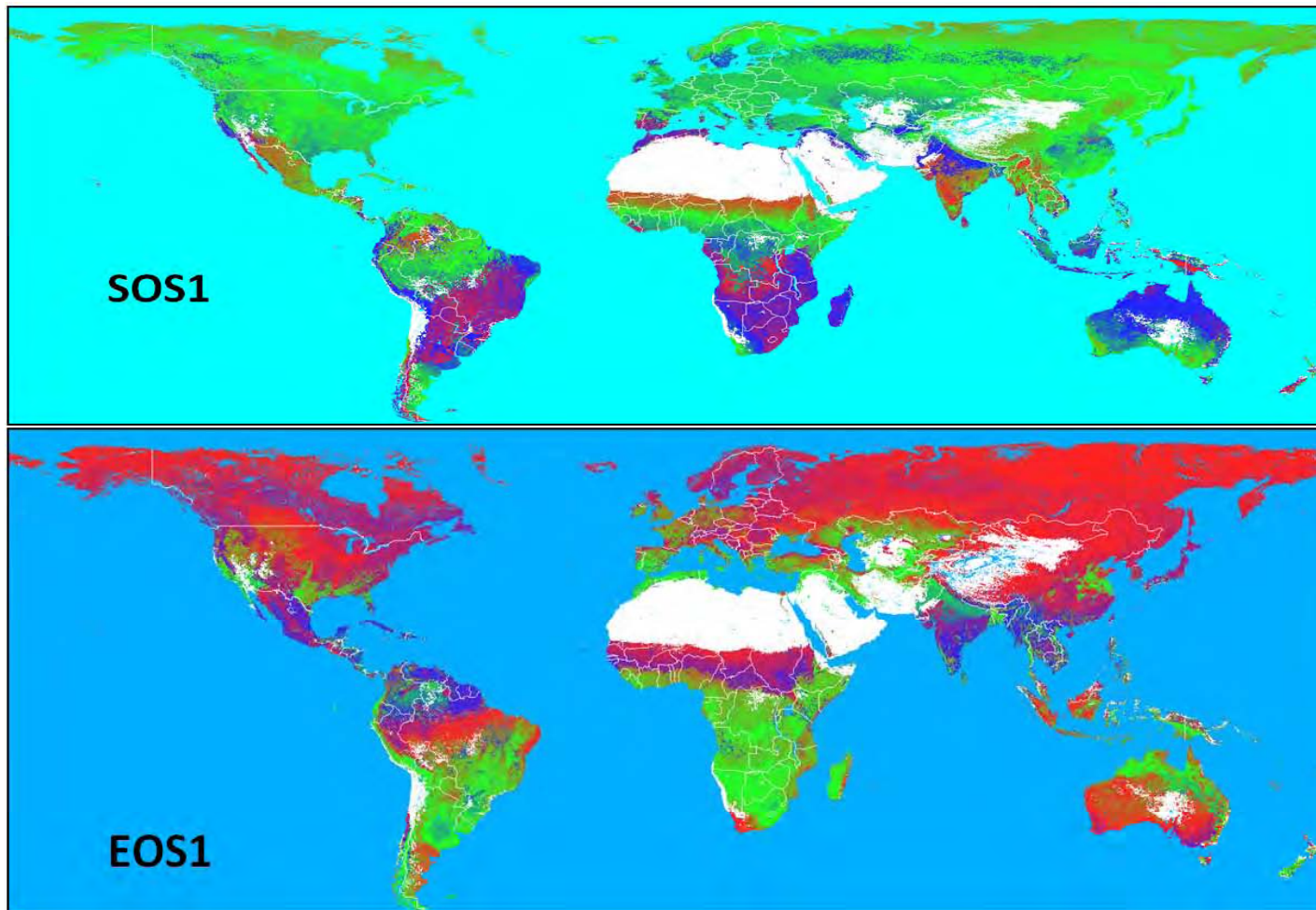
% of crop area affected by drought



VHI temporal average value

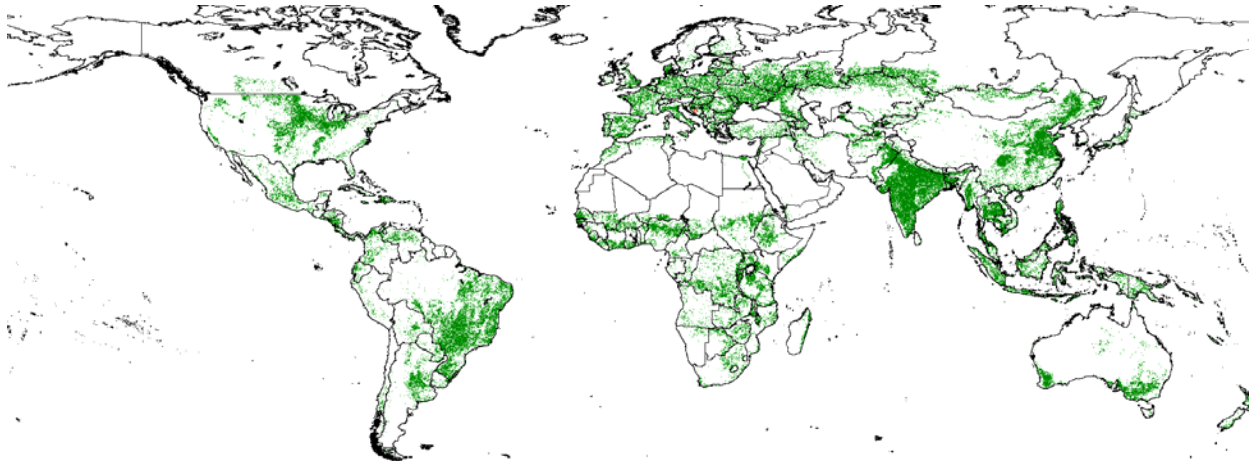


i. Temporal aggregation - defining SOS (start of growing season) & EOS (end of growing season)



SOS and EOS of the first season, as derived from the long term NDVI averages of SPOT-VGT (roi GLD, 21 km resolution).

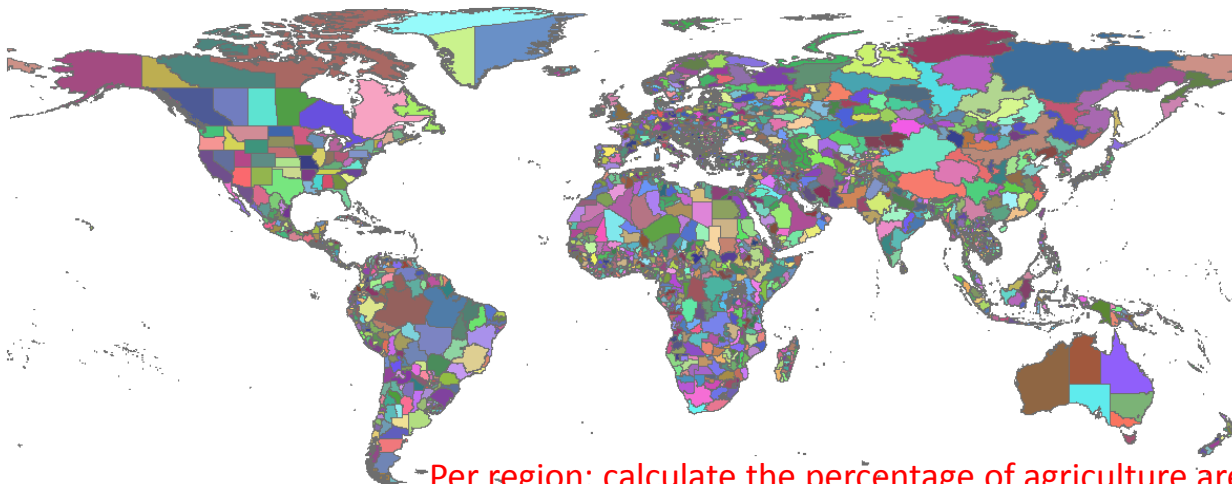
ii. Only crop pixels → Crop Mask



Compiled by JRC-
FoodSec from:

- GlobCover V2.2
- Corine-2000
- AfriCover
- ...

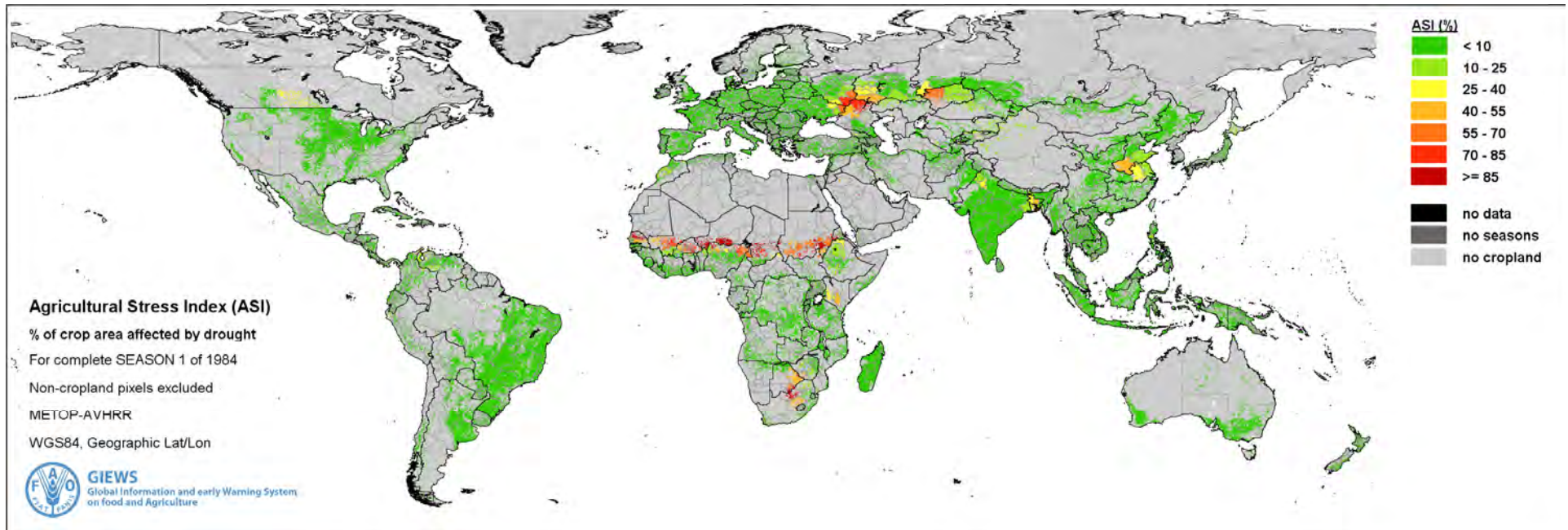
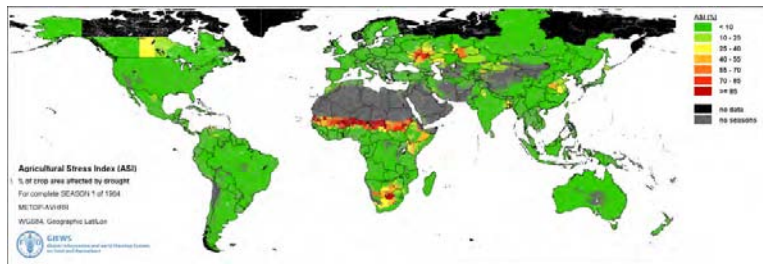
iii. Per administrative unit → Spatial Aggregation on GAUL1 level



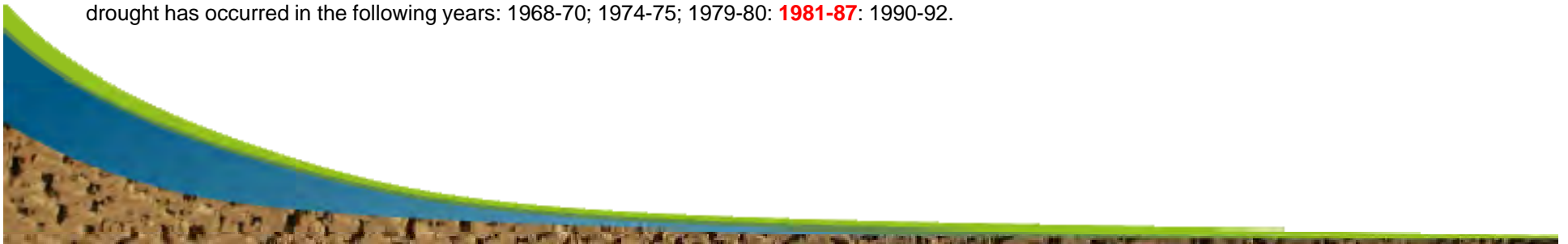
GAUL1 → Global
Administrative Unit
Layers

Per region: calculate the percentage of agriculture area affected by drought
→ Pixels with Vegetation Health Index < 35 %

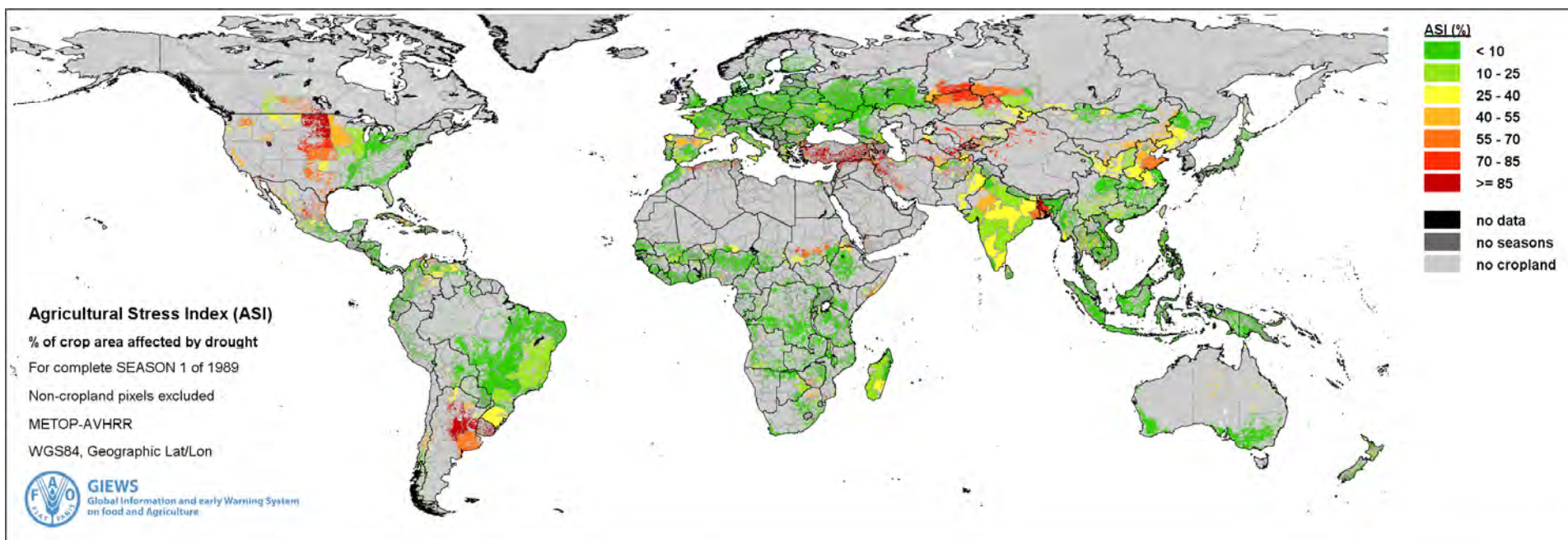
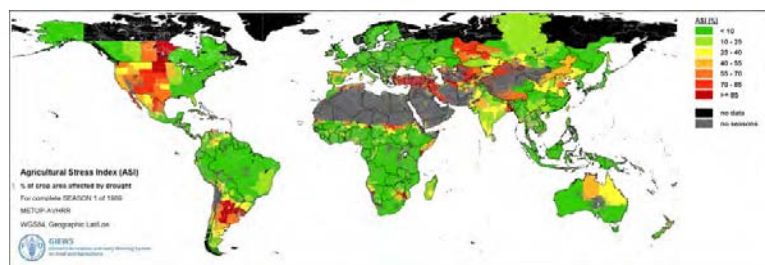
1984



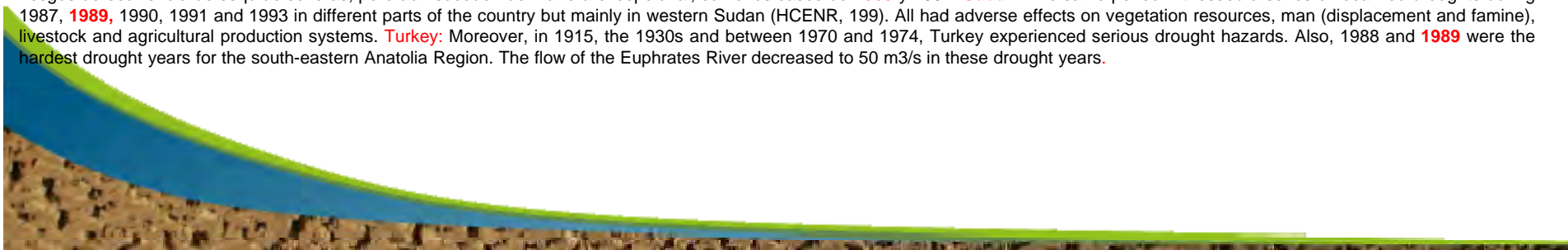
Africa: 1981 – 1984. During the crisis, an astounding 20 nations of Africa were under severe drought. Entire rivers and lakes completely dried up. Up to 20,000 people starved to death each month. Although the total number of people who perished is not completely known, it is estimated that over 1 million people died as a direct result of the drought. **Sahel:** The worst drought in the Sahel during the early-mid 1980's occurred the year 1984 affecting most Sahel countries. **Botswana:** It is a country that is prone to drought. Since independence, drought has occurred in the following years: 1968-70; 1974-75; 1979-80: **1981-87**: 1990-92.



1989



USA Another significant drought in the United States occurred during 1988 and 1989. Following a milder drought in the Southeastern United States and California the year before, this drought spread from the Mid-Atlantic, Southeast, Midwest, Northern Great Plains and Western United States. This drought was widespread, unusually intense and accompanied by heat waves which killed around 4800 to 17000 people across the United States and also killed livestock across the United States. ^[citation needed] One particular reason that the Drought of 1988 became very damaging was farmers might have farmed on land which was marginally arable. Another reason was pumping groundwater near the depletion mark. The Drought of 1988 destroyed crops almost nationwide, residents' lawns went brown and water restrictions were declared many cities. This drought was very catastrophic for multiple reasons; it continued across the Upper Midwest States and North Plains States during 1989, not officially ending until 1990.[28] **Canada**; The drought also affected Canada in certain divisions. **Argentina**: Al haber más precipitaciones se reducen los riesgos de ocurrencia de sequías severas, pero aún suceden de manera excepcional, como los casos de 1989 y 1997. **Sudan**: The same period witnessed a series of localized droughts during 1987, 1989, 1990, 1991 and 1993 in different parts of the country but mainly in western Sudan (HCENR, 199). All had adverse effects on vegetation resources, man (displacement and famine), livestock and agricultural production systems. **Turkey**: Moreover, in 1915, the 1930s and between 1970 and 1974, Turkey experienced serious drought hazards. Also, 1988 and 1989 were the hardest drought years for the south-eastern Anatolia Region. The flow of the Euphrates River decreased to 50 m³/s in these drought years.



United States - % Crop area affected by drought (ASI)

dekad 1 March 1989

dekad 3 June 1989

dekad 2 March 1989

dekad 3 March 1989

dekad 2 June 1989

1989

dekad 1 April 1989

dekad 1 June 1989

dekad 2 April 1989

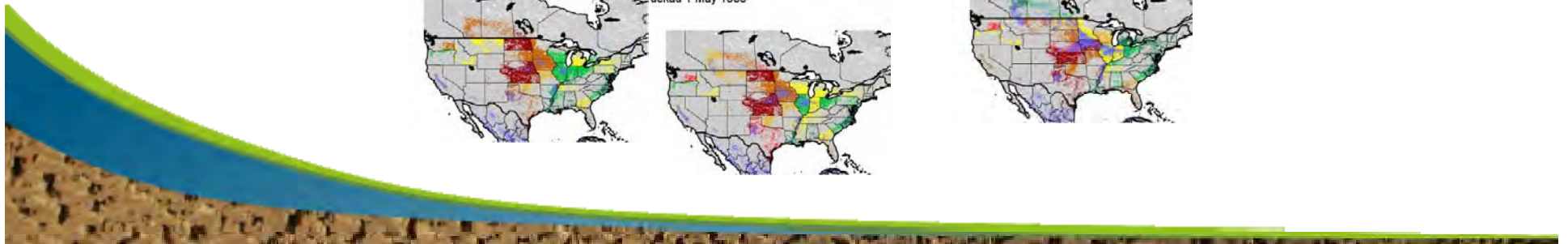
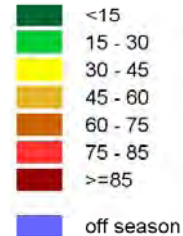
dekad 3 May 1989

dekad 2 April 1989

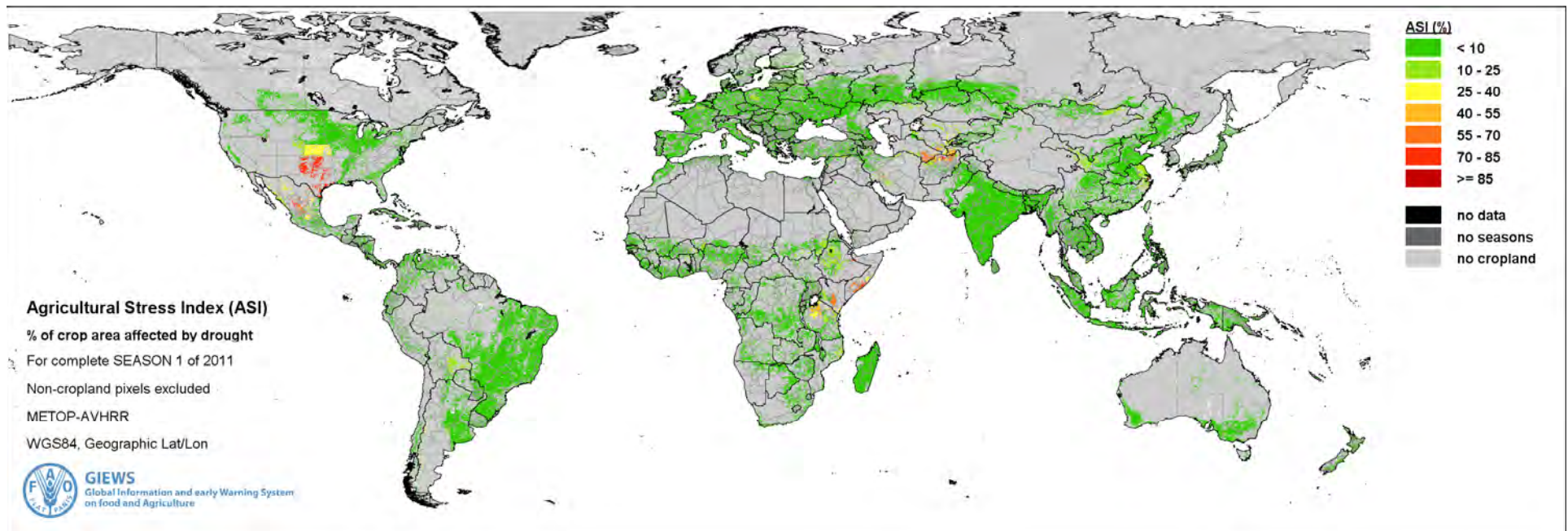
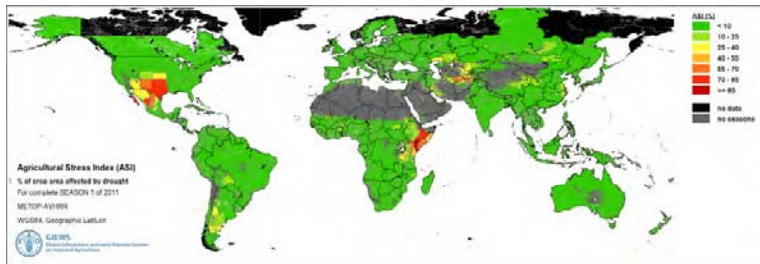
dekad 2 May 1989

dekad 1 May 1989

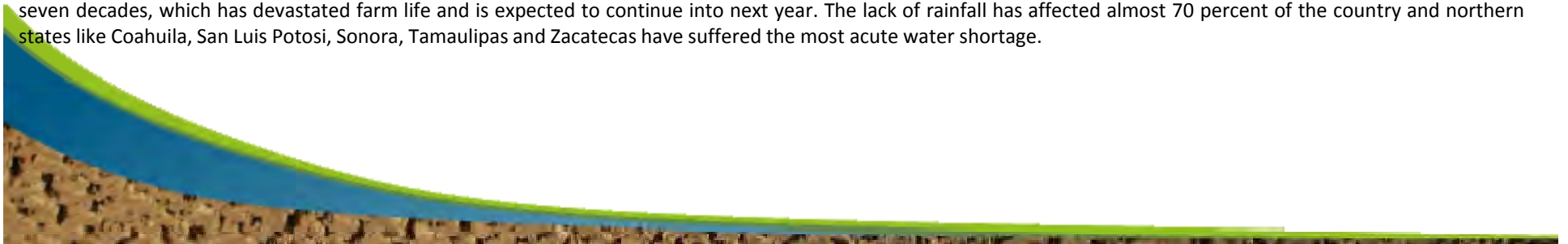
ASI (%)



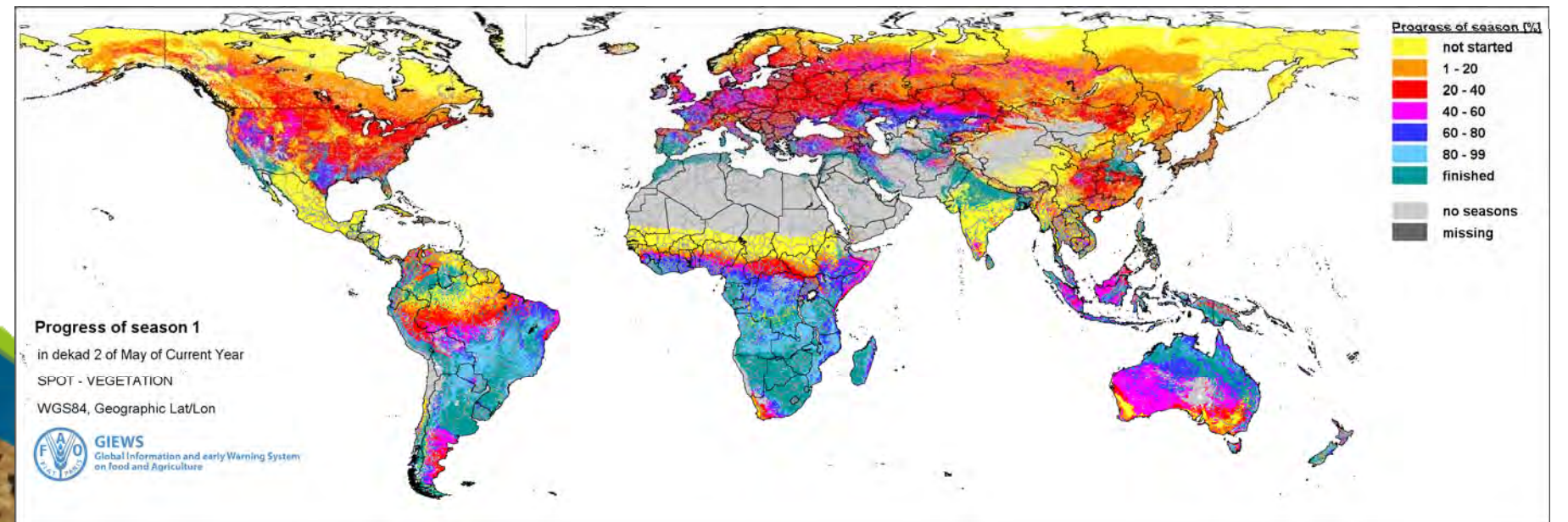
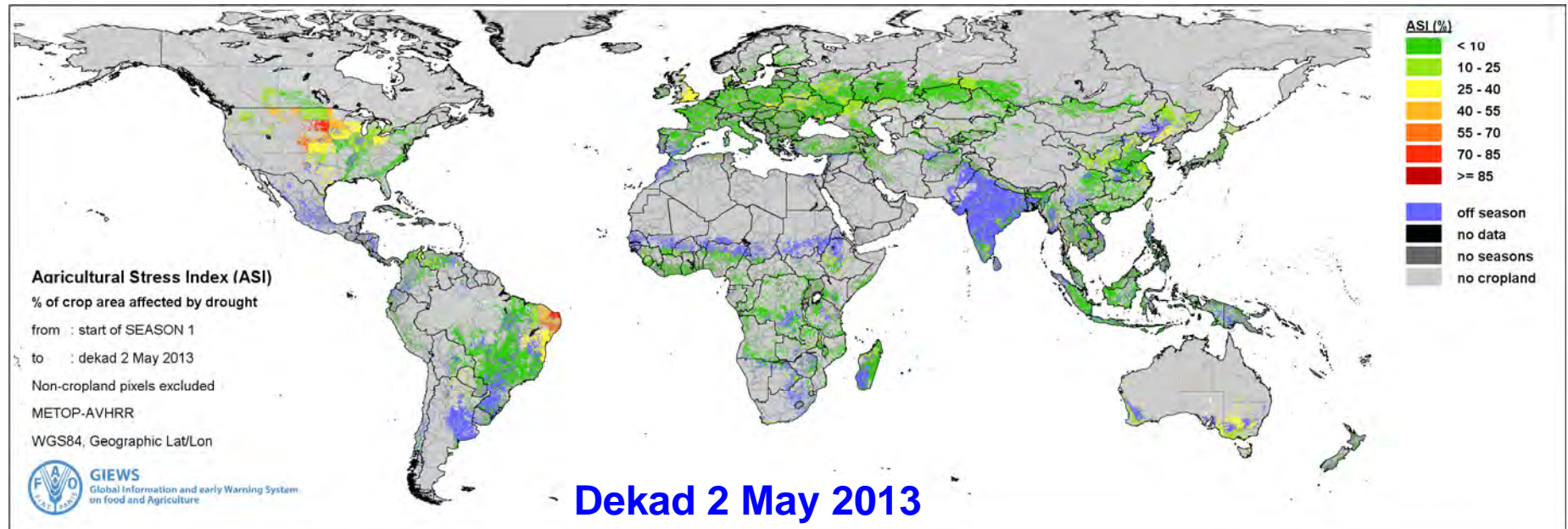
2011



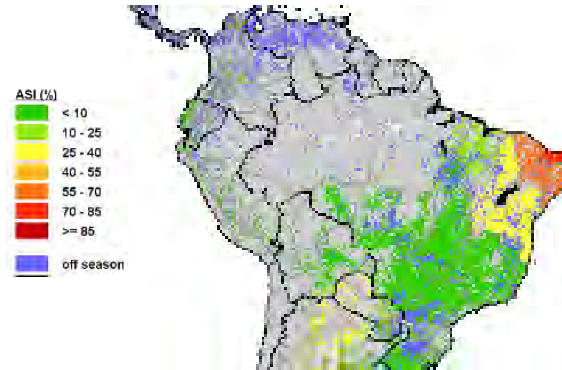
Eastern Africa: Since mid-July 2011, a severe drought has been affecting the entire East Africa region.^[6] Said to be "the worst in 60 years",^[7] the drought has caused a severe food crisis across Somalia, Djibouti, Ethiopia and Kenya that threatens the livelihood of 9.5 million people. **United States:** Much of Texas is bone dry, with scarcely any moisture to be found in the top layers of soil. Grass is so dry it crunches underfoot in many places. The nation's leading cattle-producing state just endured its driest seven-month span on record, and some ranchers are culling their herds to avoid paying supplemental feed costs. **Mexico:** Mexico is being battered its worst drought in seven decades, which has devastated farm life and is expected to continue into next year. The lack of rainfall has affected almost 70 percent of the country and northern states like Coahuila, San Luis Potosi, Sonora, Tamaulipas and Zacatecas have suffered the most acute water shortage.



ASIS: Real time analysis



Brazil (Semi-arido)



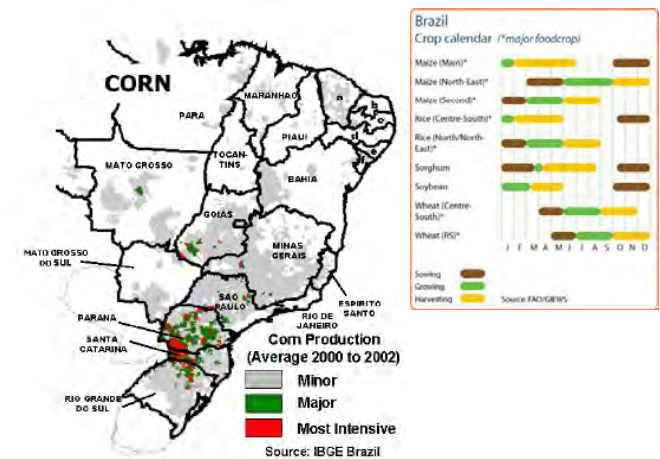
Produtores do Semiárido afetados pela seca têm prazo até 31 de maio para solicitar crédito emergencial

De acordo com o Ministério da Integração Nacional, ainda podem ser contratados cerca de R\$ 150 milhões.

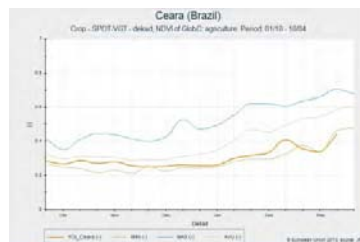
Provetistas e agricultores familiares dos municípios do Semiárido que sofrem os efeitos da estiagem têm até 31 de maio para solicitar recursos da linha emergencial de crédito disponibilizada pelo governo federal para recuperação das áreas. Segundo o Ministério da Integração Nacional, ainda podem ser contratados cerca de R\$ 150 milhões em recursos do Fundo Constitucional de Financiamento do Nordeste (FNE).

Até hoje, foram destinados, desde maio do ano passado, R\$ 2,4 bilhões para a linha de crédito, operado pelo Banco do Nordeste do Brasil (BNB). Até agora, foram feitas aproximadamente 300 mil operações de crédito por meio da linha emergencial e 22 mil operações estão sendo analisadas pelo Banco do Nordeste.

De acordo com o diretor do Departamento de Inspeção, Normas e Análise de Risco da pasta, José Wanderley Lima Barreto, a medida é para ajudar o impacto da escassez de chuvas sobre o homem do campo e proteger a produção agropecuária da região. Com os recursos do financiamento, produtores familiares podem comprar, por exemplo, ração para seu rebanho, pagando à vista e tendo um prazo mais longo para amortizar a empreitada.



<http://g1.globo.com/rn/rio-grande-do-norte/noticia/2013/03/reporter-fotografico-registra-efeitos-da-seca-no-interior-do-rn.html>



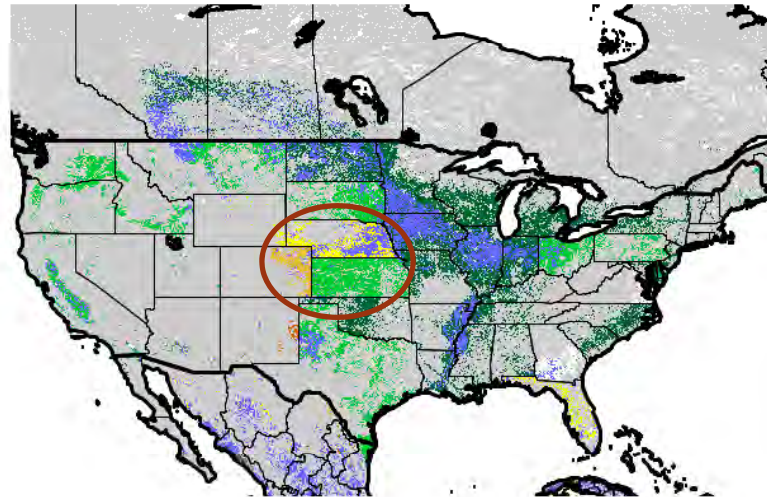
Semi-arido of Brazil affected by drought however the most productive agriculture areas are in good conditions

United States

United States - % Crop area affected by drought (ASI)

from: start of SEASON 1
to : dekad 2 April 2013

ASI (%)



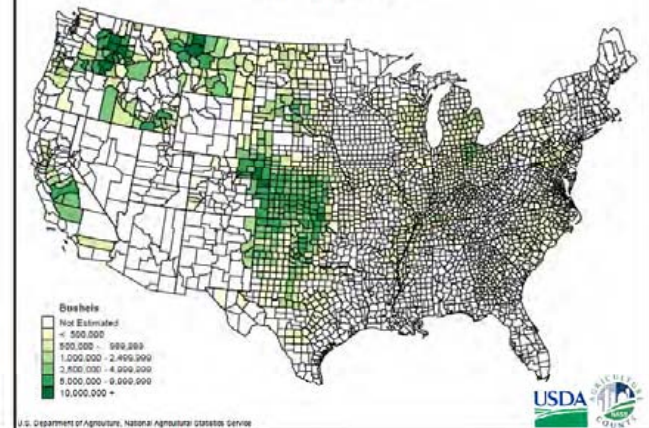
FAO/GIEWS

Projection: Geographic, WGS 84 - Resolution: 1km

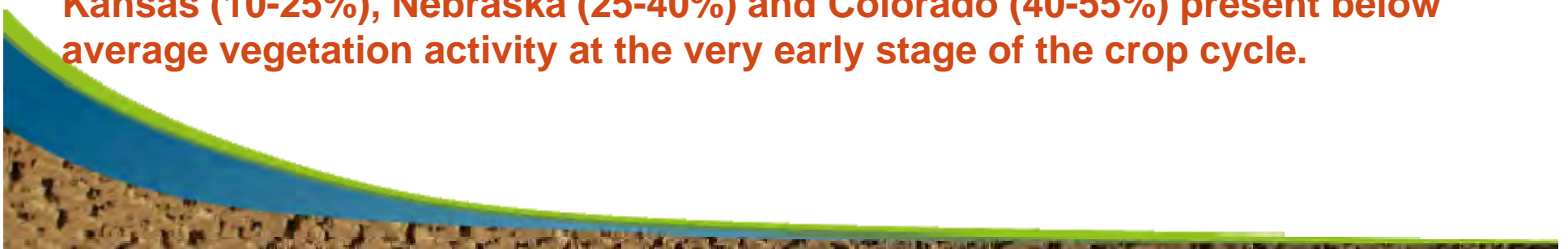
Sources : METOP/AVHRR - Vectors from FAO Gaul



Winter Wheat 2010
Production by County
for Selected States



Kansas (10-25%), Nebraska (25-40%) and Colorado (40-55%) present below average vegetation activity at the very early stage of the crop cycle.



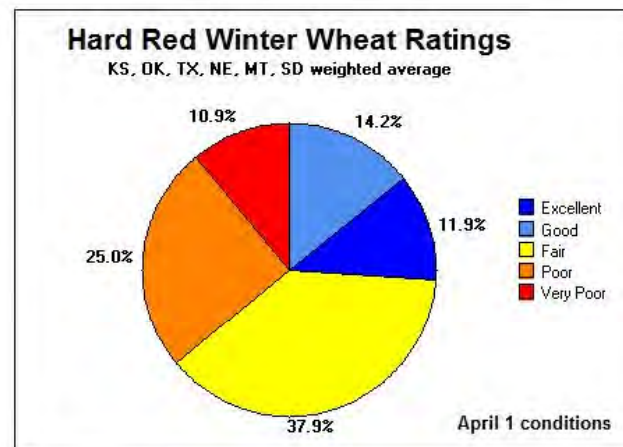
Field report, United States

Winter Wheat Condition - Selected States: Week Ending April 21, 2013

[National crop conditions for selected States are weighted based on 2012 planted acreage]

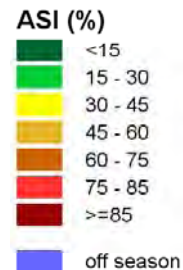
State	Very poor (percent)	Poor (percent)	Fair (percent)	Good (percent)	Excellent (percent)
Arkansas	5	3	34	49	9
California	-	-	15	30	55
Colorado	25	31	35	9	-
Idaho	1	1	20	65	13
Illinois	-	3	21	63	13
Indiana	1	4	27	47	21
Kansas	16	21	33	27	3
Michigan	4	8	31	53	4
Missouri	-	1	28	58	13
Montana	3	0	37	44	7
Nebraska	13	30	46	11	-
North Carolina	-	3	22	61	14
Ohio	1	4	23	60	12
Oklahoma	13	23	37	25	2
Oregon	-	5	21	67	7
South Dakota	22	31	41	6	-
Texas	31	29	28	11	1
Washington	1	2	19	65	13
18 States	14	19	32	30	5
Previous week	12	19	33	31	5
Previous year	3	7	27	48	15

- Represents zero.

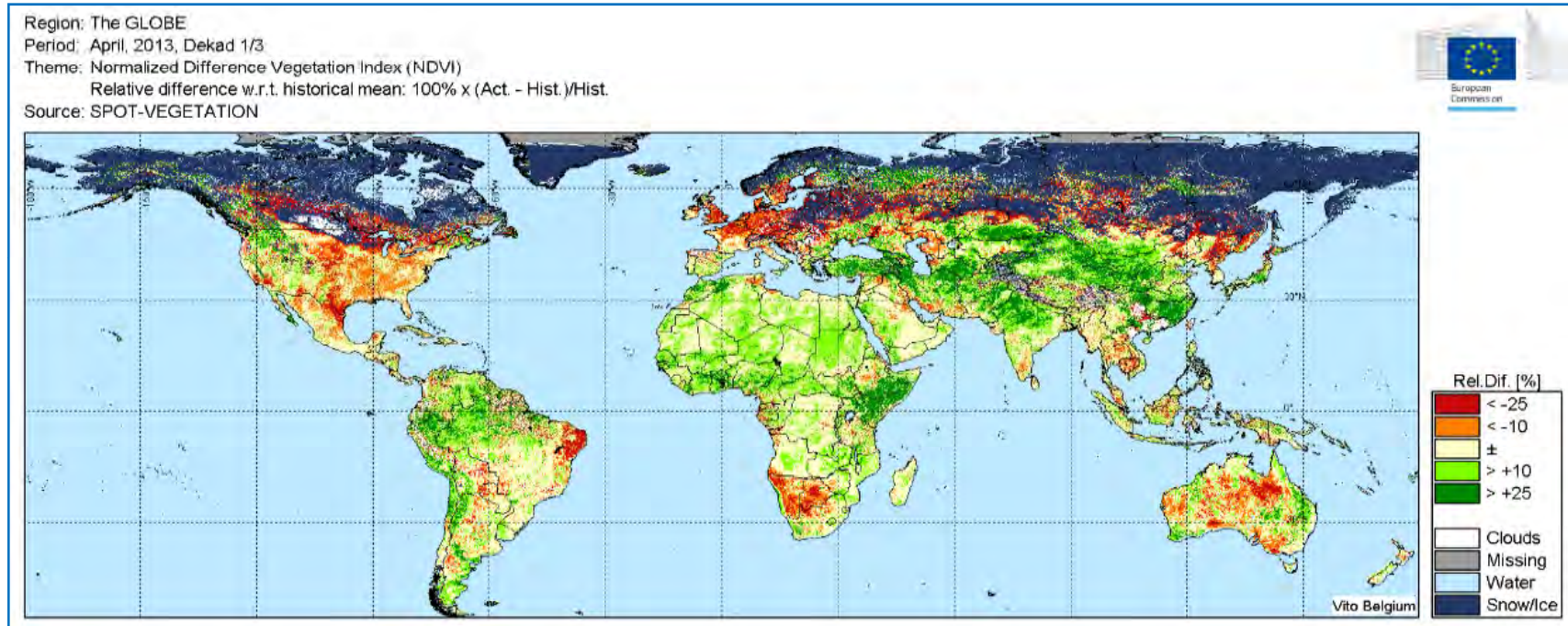


Data source USDA

A map of the United States showing the distribution of the four major groups of Native Americans. The Northwest group is in the Pacific Northwest, the Southwest group is in the Southwest, the Eastern Woodlands group is in the Eastern half of the continent, and the Great Plains group is in the Great Plains region.



Classical remote sensing analysis based on anomalies



Spatial unmixing NOAA images to METOP standard

- The NOAA data set from 1984-2007 is hereby remapped and rescaled to the METOP standards (resolution and spectral values).

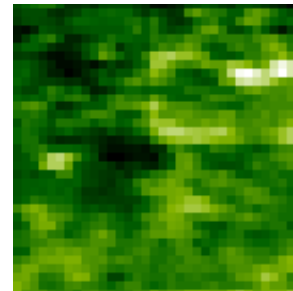
***NOAA 16 km
July 2000***



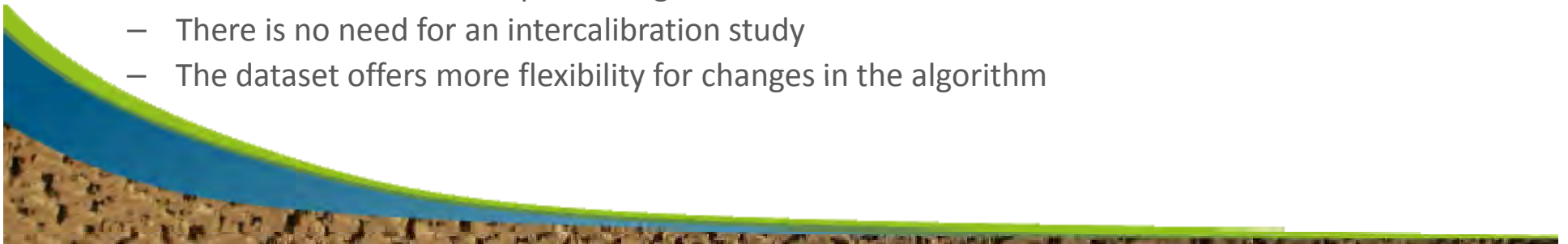
spatial weighting matrix
based on the relation
between the long term
average of METOP and
NOAA.



***Simulated METOP 1 km
July 2000***



- Two datasets are combined for the use in ASIS:
 - Simulated METOP images from NOAA [1984-march 2007]
 - True METOP images [march 2007-today]
- Pro's:
 - It is a one-time operation on NOAA STAR. There will be only one processing chain for METOP, there is no need to maintain a processing chain for NOAA STAR.
 - There is no need for an intercalibration study
 - The dataset offers more flexibility for changes in the algorithm



Example of NOAA unmixing case for 4 by 4 pixels

$$\frac{Y_{(year,dek)}}{\mu_{Y(dek)}} = \frac{X_{(year,dek)}}{\mu_{X(dek)}} \rightarrow Y_{(year,dek)} = \frac{\mu_{Y(dek)}}{\mu_{X(dek)}} * X_{(year,dek)}$$

- Y = METOP at 1 km, X = NOAA-STAR converted to 1 km
- $Y_{(year,dek)}$, $X_{(year,dek)}$ are the actual values for a given year/dekad.
- $\mu_{Y(dek)}$, $\mu_{X(dek)}$ are the long term averages, calculated for the period march 2007 – end 2011 for both sensors, for the concerned dekad.

METOP
LTA [07-11, dekad]

0,10	0,30	0,15	0,18
0,62	0,25	0,02	0,34
0,82	0,68	0,19	0,38
0,68	0,62	0,65	0,55

÷

NOAA
LTA [07-11, dekad]

0,35

=

0,3

X

NOAA
ACTUAL NDVI [year, dekad]

0,29	0,86	0,43	0,51
1,77	0,71	0,06	0,97
2,34	1,94	0,54	1,09
1,94	1,77	1,86	1,57

Spatial weighting matrix
[dekad]

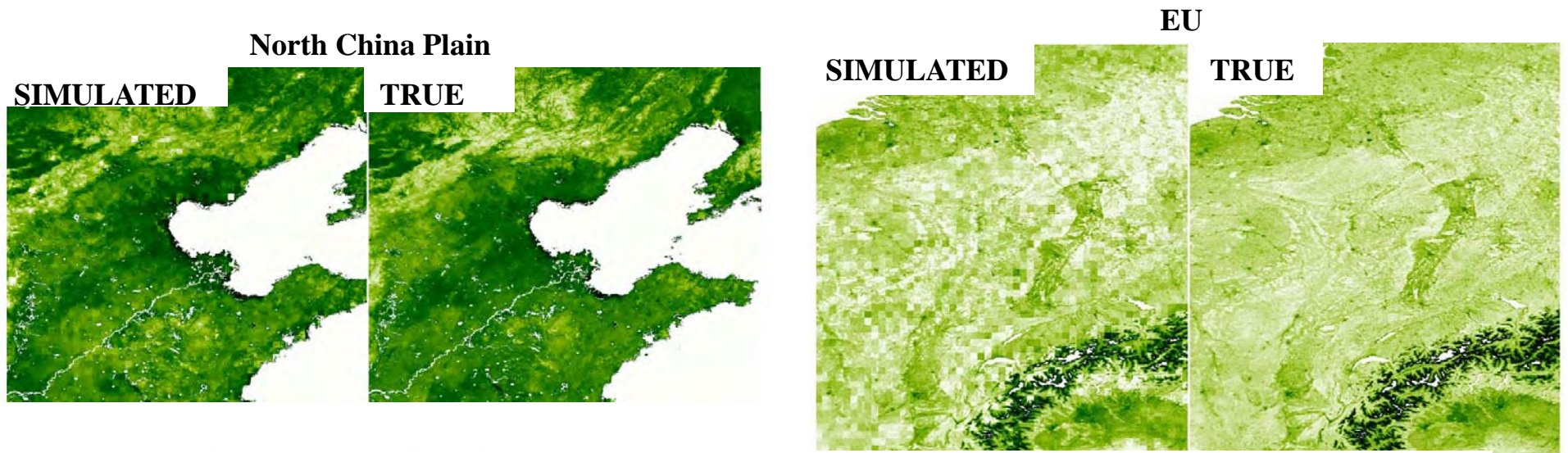


0,09	0,26	0,13	0,15
0,53	0,21	0,02	0,29
0,70	0,58	0,16	0,33
0,58	0,53	0,56	0,47

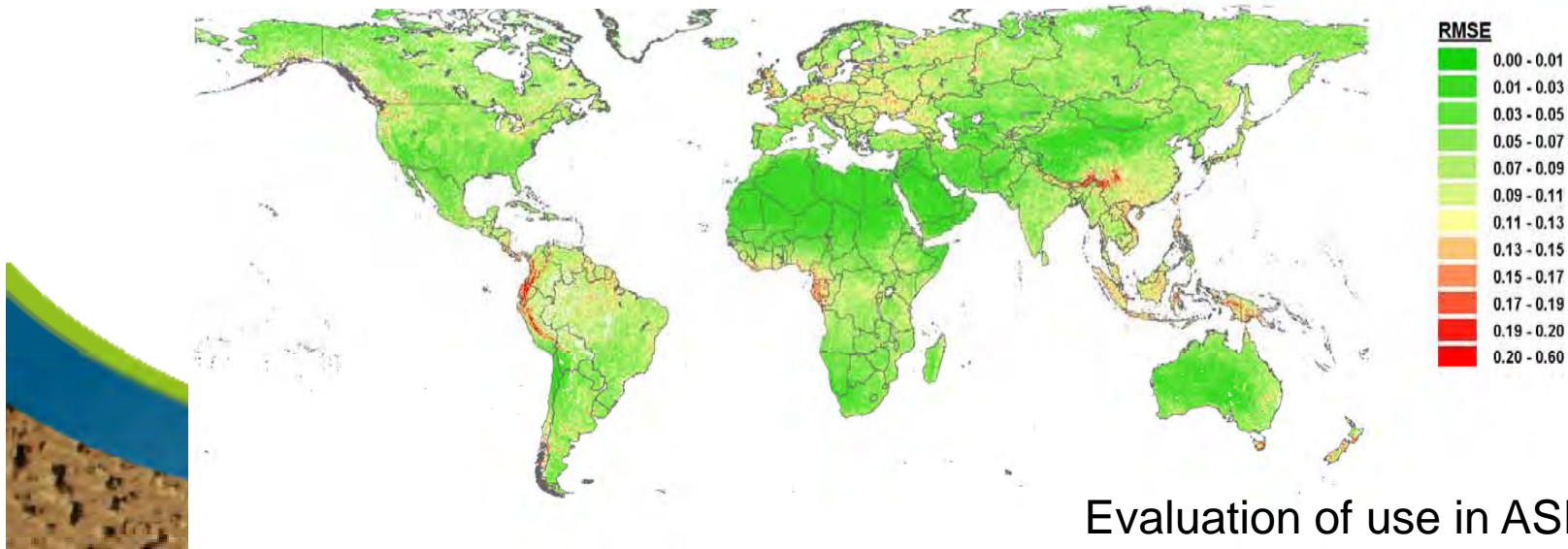
METOP
SIMULATED NDVI [year, dekad]



Validation



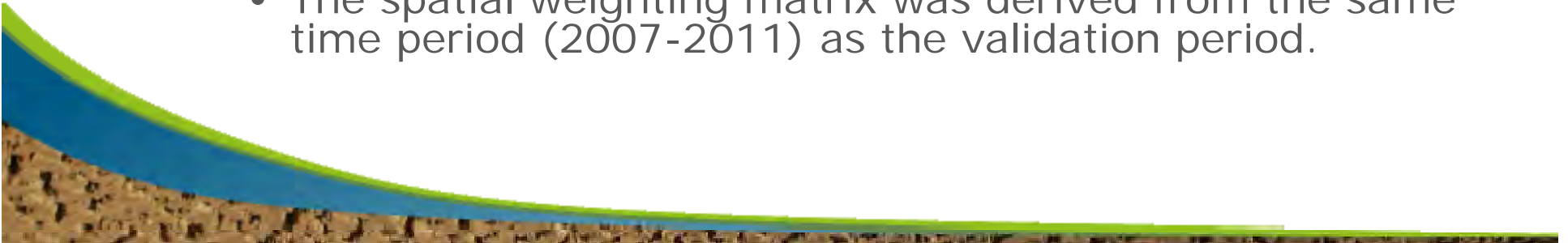
Root Mean Squared Error for simulated vs true NDVI images for 36 dekads of 2008



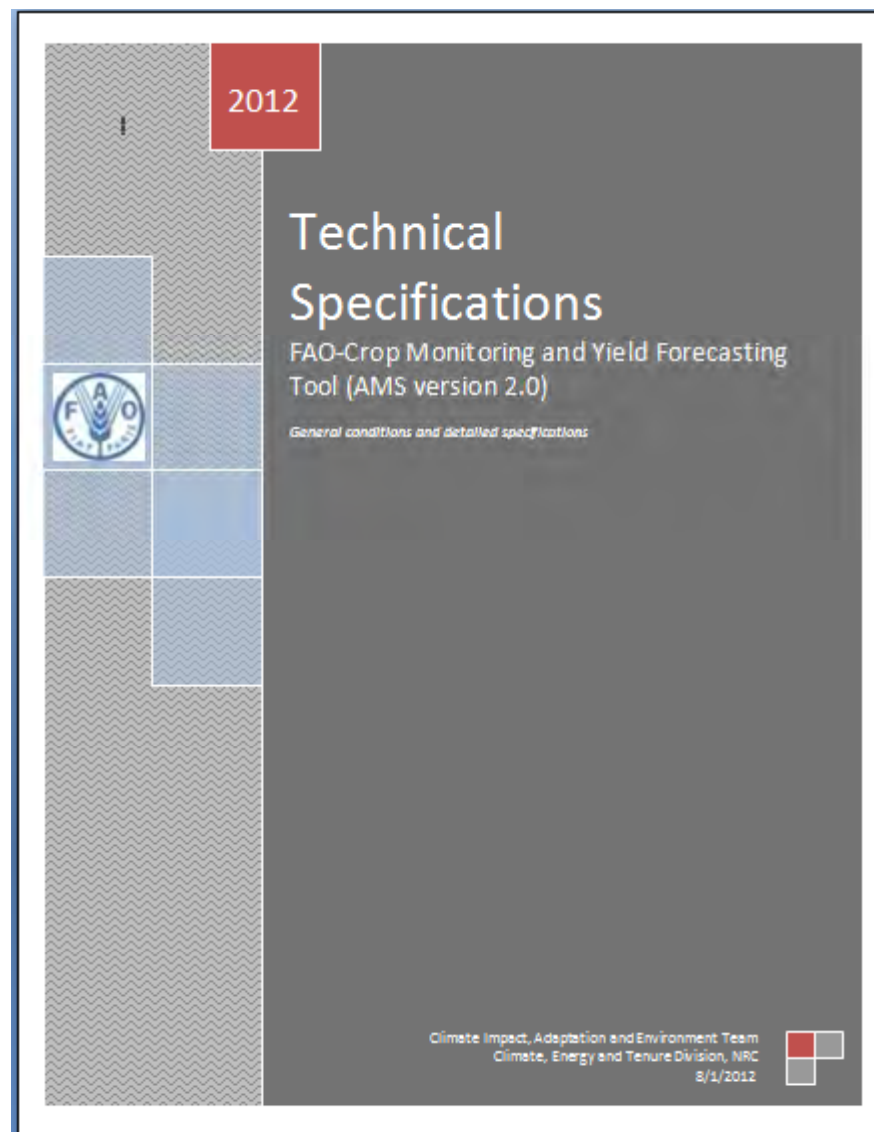
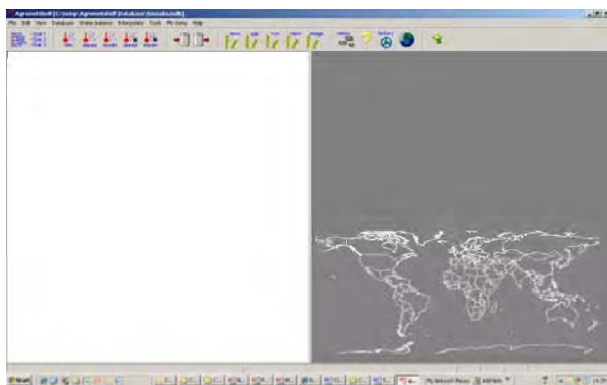
Evaluation of use in ASIS see further

Limitations of method 5

- *Inter-annual landscape variability*
 - The method assumes that the distribution of the 1 km METOP LTA [2007-2011] did not change over the last 30 years. So it assumes a stable inter-annual landscape variability.
- *non-linear scaling of NDVI*
 - The method assumes a linear scaling. This assumption is true for the individual red and NIR values but not for the resulting NDVI's. The result is that the calculated NDVI values within the 16 km blocks have a narrower range than would be expected when applying the method on red and NIR values. However, they are highly correlated ($R^2 > 0.99$).
- *No independent validation possible*
 - The spatial weighting matrix was derived from the same time period (2007-2011) as the validation period.



FAO Crop Monitoring and Yield Forecasting Tool (AgroMetShell version 2.0)



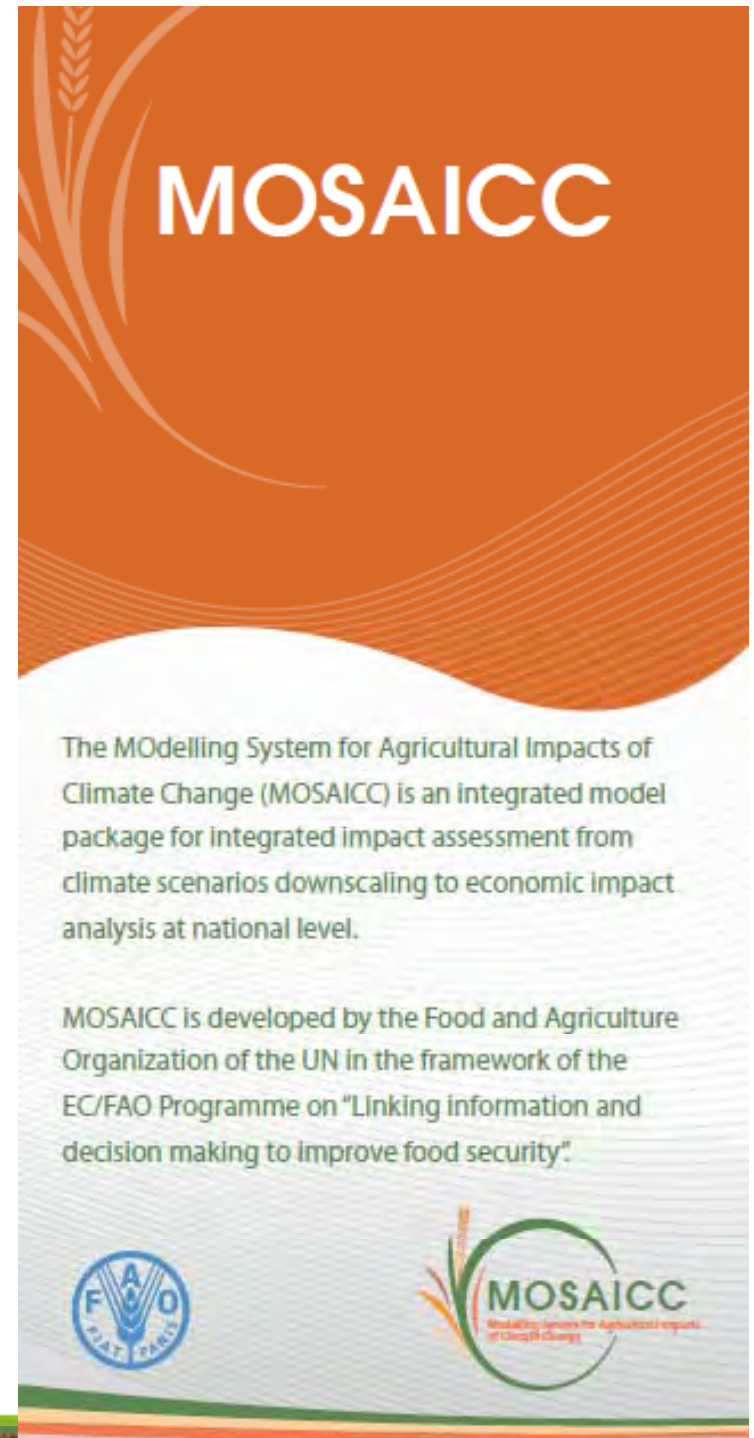
Climate Change Impact tool development: MOSAICC

Objectives

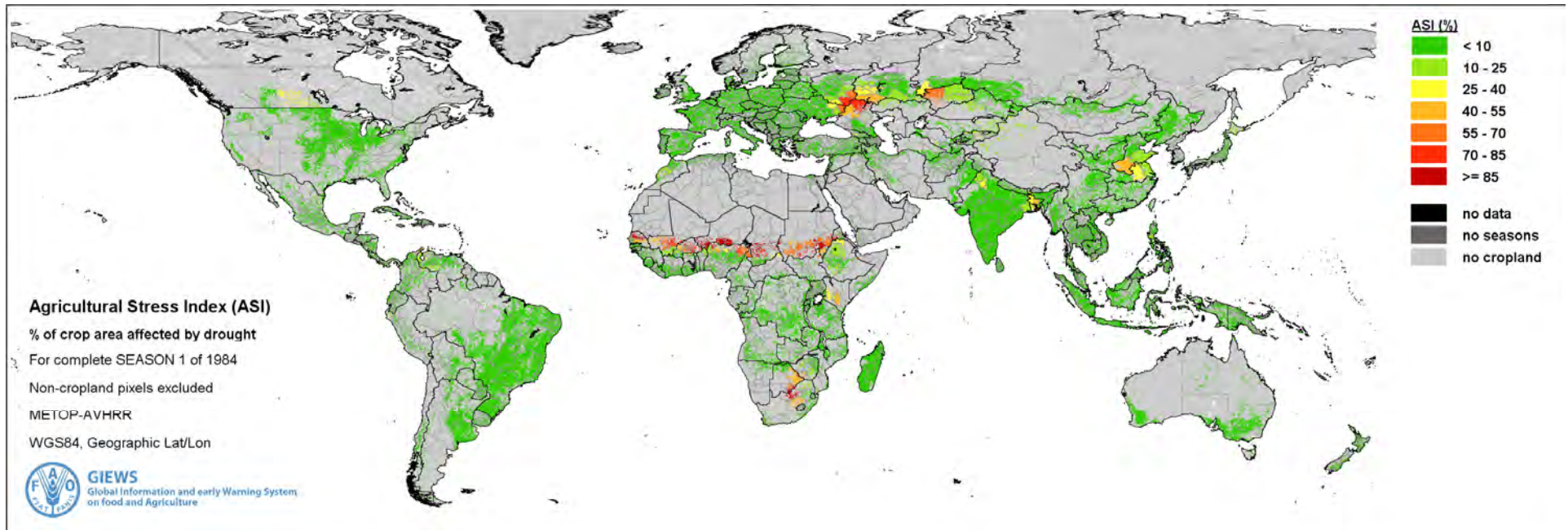
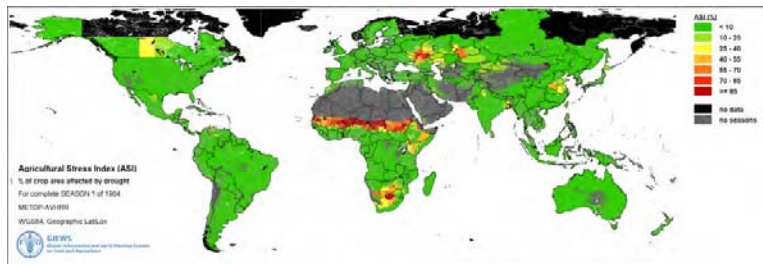
- **MO**delling **S**ystem for **A**gricultural **I**mpacts of **C**limate **C**hange
- Integrated impact assessment on crop yields, from climate data handling to economic assessment
- Provides information to support decision-making at national level
- Delivered to national institutions with training

*Implementation phase funding by EC/FAO
Programme "Global Governance for Hunger
Reduction"*

www.fao.org/climatechange/mosaicc/en/



1984

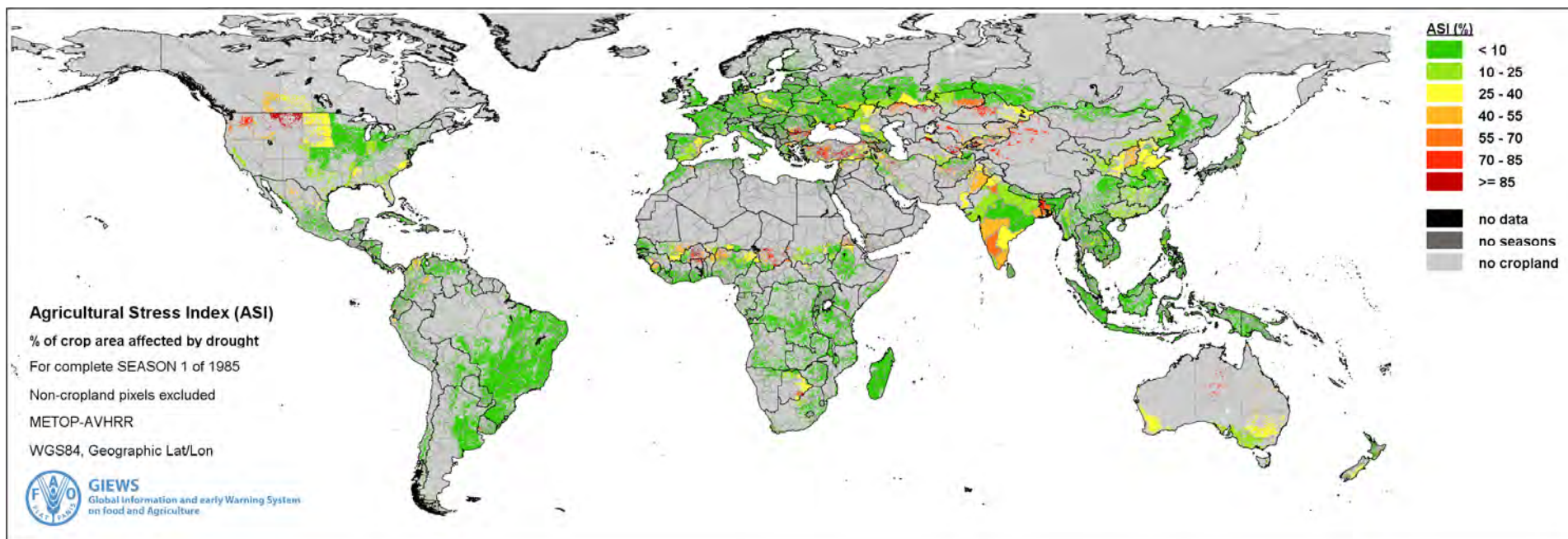
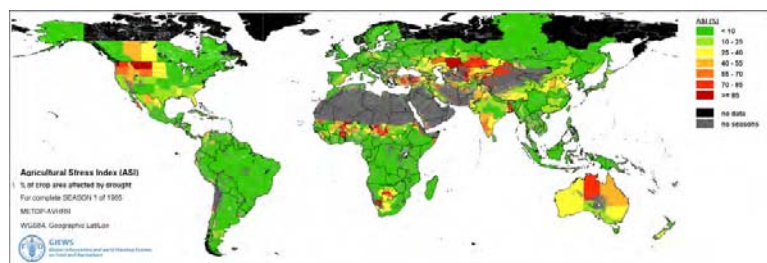


Africa: 1981 – 1984. During the crisis, an astounding 20 nations of Africa were under severe drought. Entire rivers and lakes completely dried up. Up to 20,000 people starved to death each month. Although the total number of people who perished is not completely known, it is estimated that over 1 million people died as a direct result of the drought. **Sahel:** The worst drought in the Sahel during the early-mid 1980's occurred the year 1984 affecting most Sahel countries. **Botswana:** It is a country that is prone to drought. Since independence, drought has occurred in the following years: 1968-70; 1974-75; 1979-80: **1981-87:** 1990-92.



Food and Agriculture Organization of the United Nations

1985

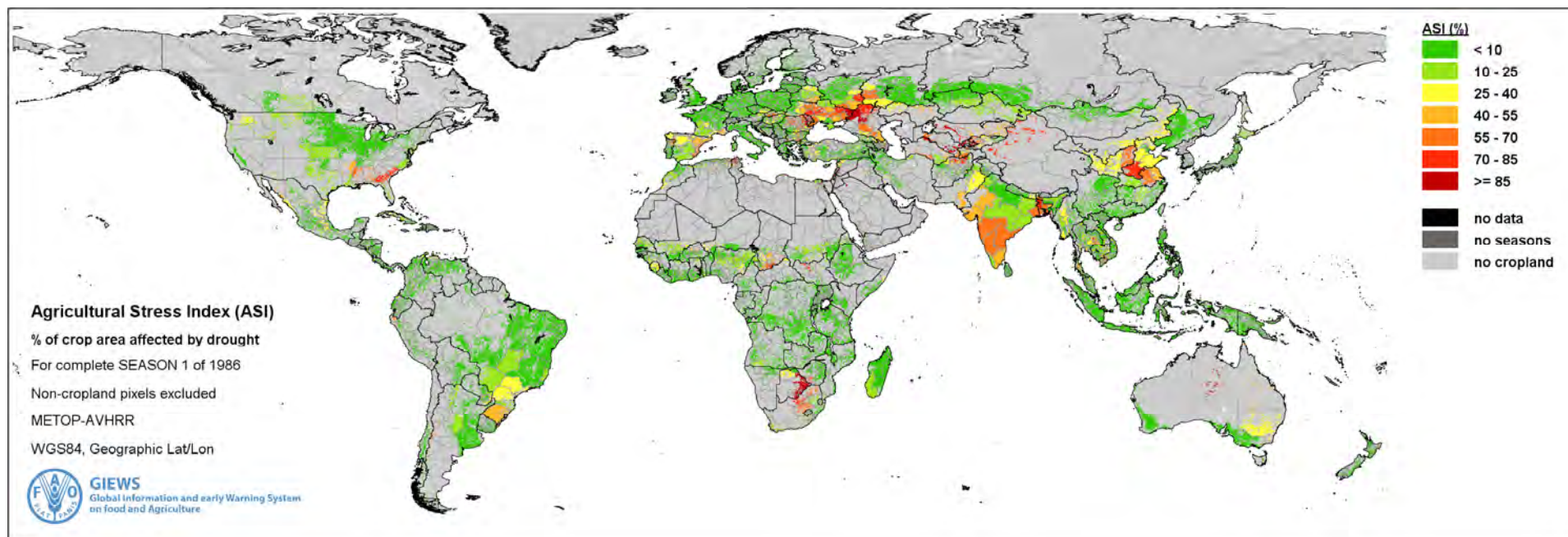
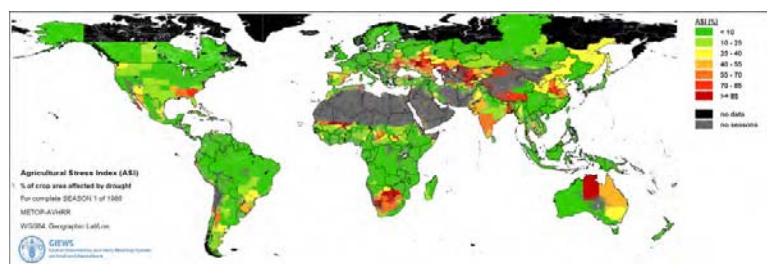


USA A severe drought struck the Southeast from 1985 through 1987. It began in 1985 from the Carolinas west-southwest into [Alabama](#), when annual rainfall was reduced by 5 to 35 percent below what was normal. Light precipitation continued into the spring of 1986, with [Atlanta, Georgia](#) recording their driest first six months on record. High amounts of precipitation during the winter of 1987 ended the drought. **Sahel** droughts of the 80's. **Botswana**: It is a country that is prone to drought. Since independence, drought has occurred in the following years: 1968-70; 1974-75; 1979-80; **1981-87**; 1990-92 (Fako, T. and Molamu, L. 1995).



Food and Agriculture Organization of the United Nations

1986



USA A severe drought struck the Southeast from 1985 through 1987. It began in 1985 from the Carolinas west-southwest into [Alabama](#), when annual rainfall was reduced by 5 to 35 percent below what was normal. Light precipitation continued into the spring of 1986, with [Atlanta, Georgia](#) recording their driest first six months on record. High amounts of precipitation during the winter of 1987 ended the drought.

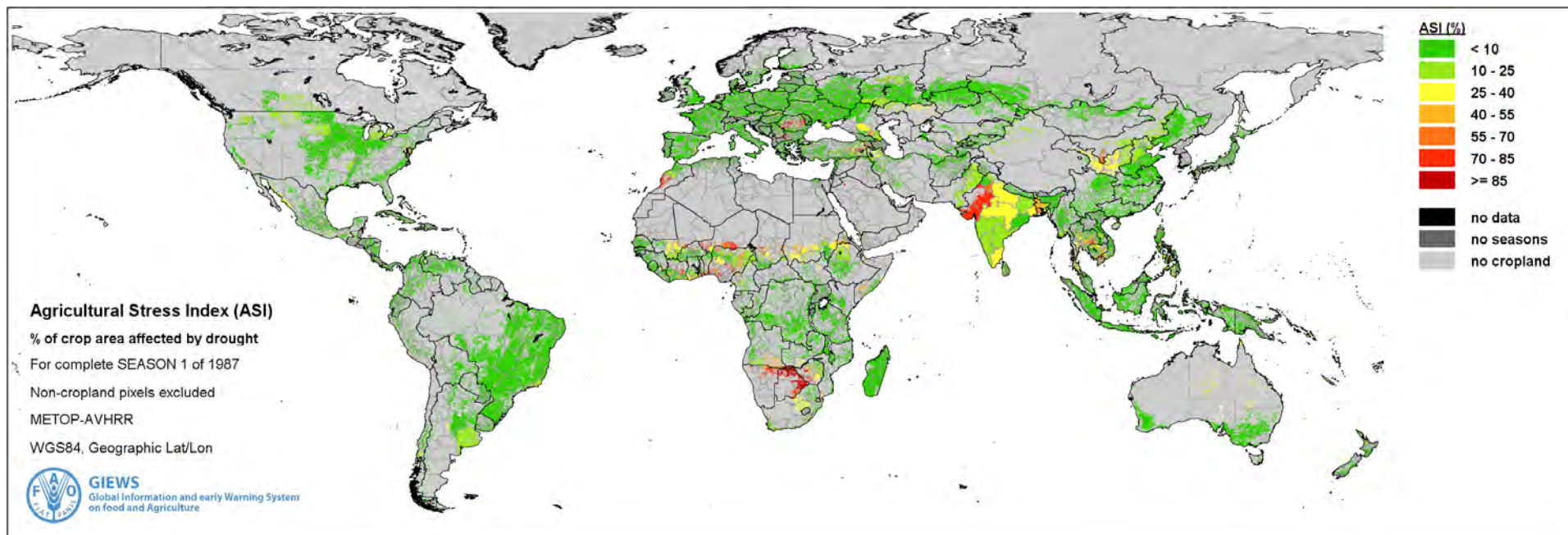
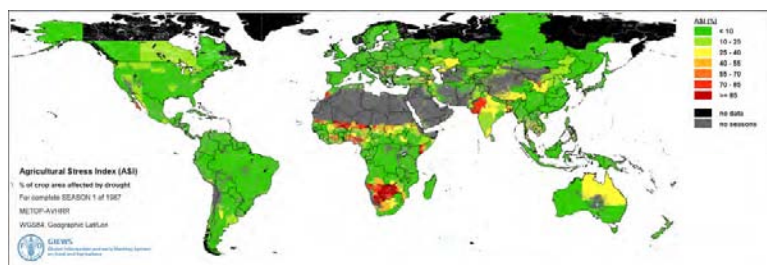
India: Of course, in 1986 and 1987, India experienced severe drought. During September and October 1986, the entire state of Haryana was hit by a drought. Crops like bajra, sugarcane, paddy, and pulses, worth a total of Rs.100 crores, were damaged.

Botswana: It is a country that is prone to drought. Since independence, drought has occurred in the following years: 1968-70; 1974-75; 1979-80; **1981-87**; 1990-92 (Fako, T. and Molamu, L. 1995).



Food and Agriculture Organization of the United Nations

1987

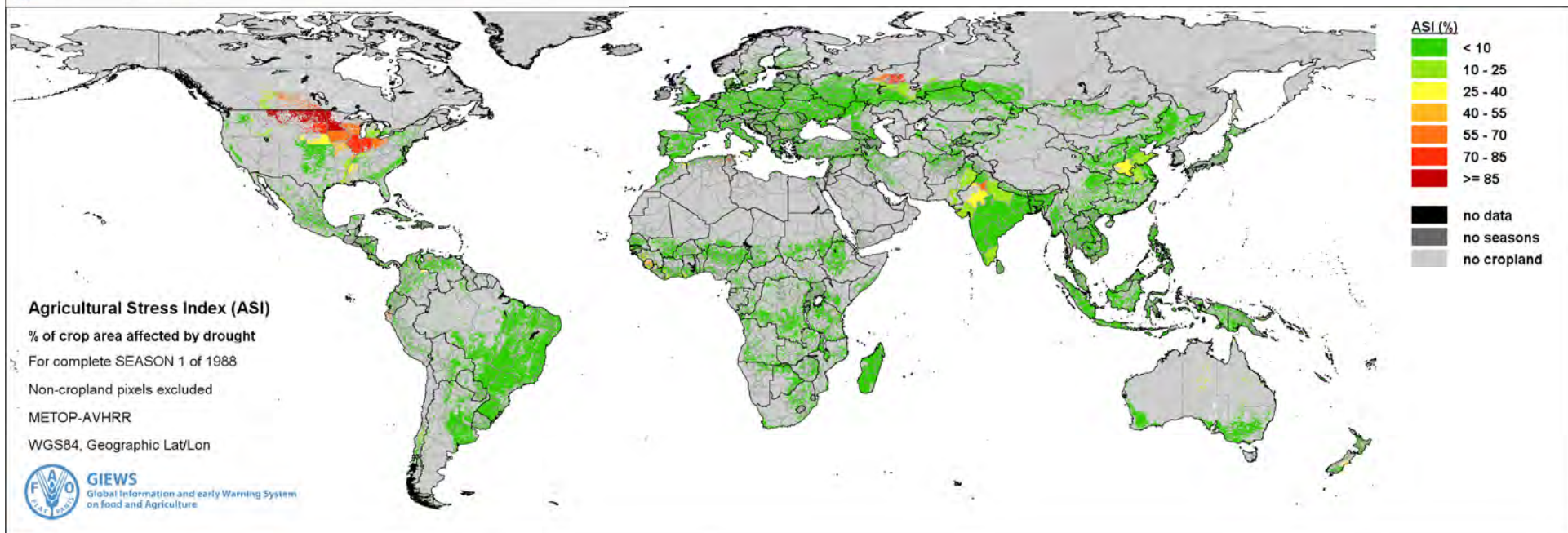
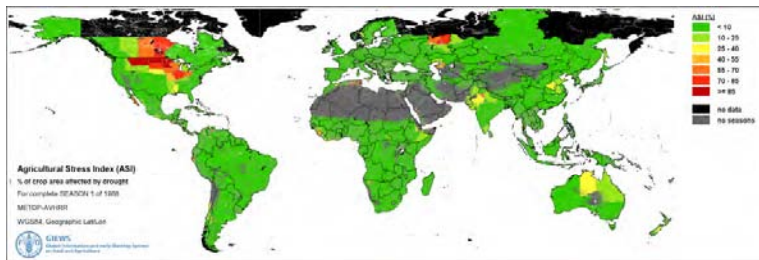


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1988

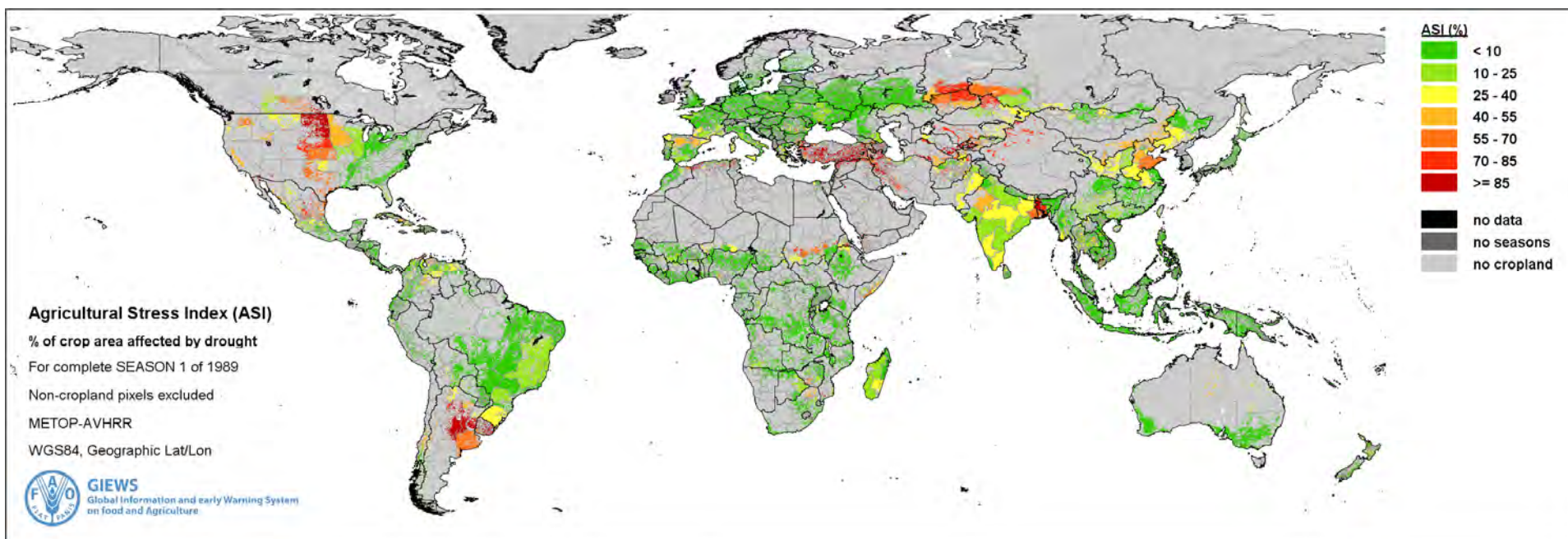
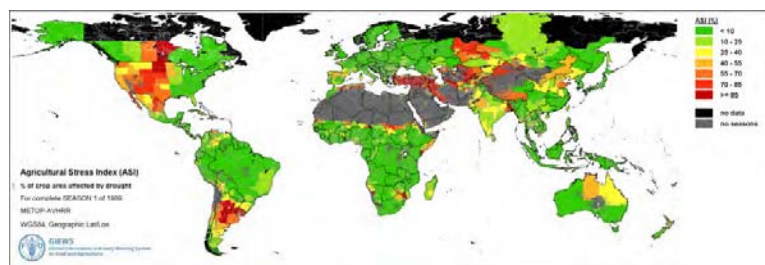


USA Another significant drought in the United States occurred during 1988 and 1989. Following a milder drought in the [Southeastern United States](#) and California the year before, this drought spread from the [Mid-Atlantic](#), Southeast, [Midwest](#), Northern Great Plains and [Western United States](#). This drought was widespread, unusually intense and accompanied by heat waves which killed around 4800 to 17000 people across the United States and also killed livestock across the United States. One particular reason that the Drought of 1988 became very damaging was farmers might have farmed on land which was marginally arable. Another reason was pumping [groundwater](#) near the depletion mark. The [Drought of 1988](#) destroyed crops almost nationwide, residents' lawns went brown and water restrictions were declared many cities. This drought was very catastrophic for multiple reasons; it continued across the Upper Midwest States and North Plains States during 1989, not officially ending until 1990.[28] The drought also affected **Canada** in certain divisions.



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1989

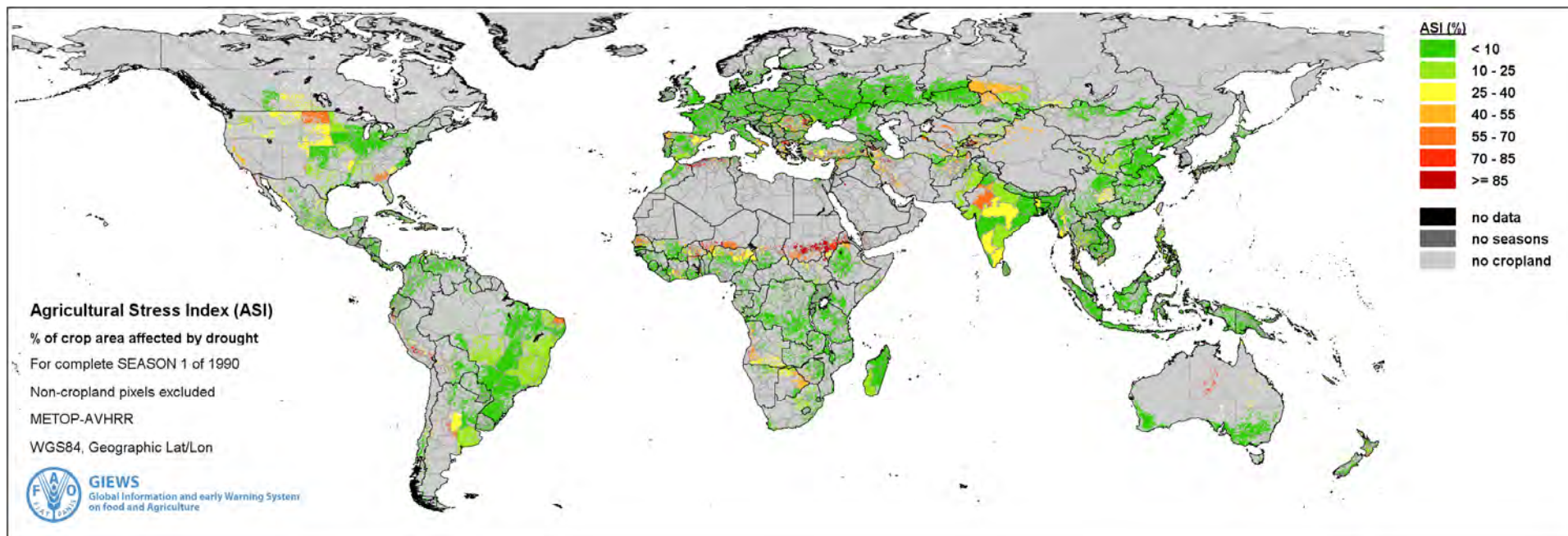
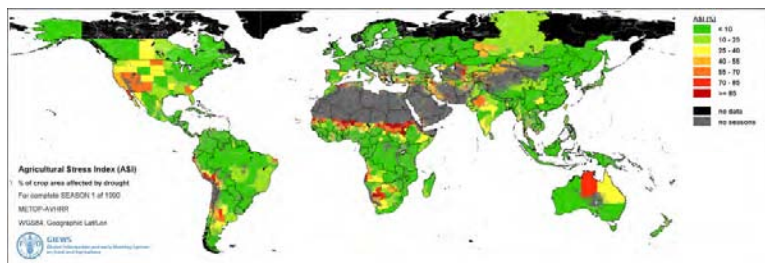


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1990

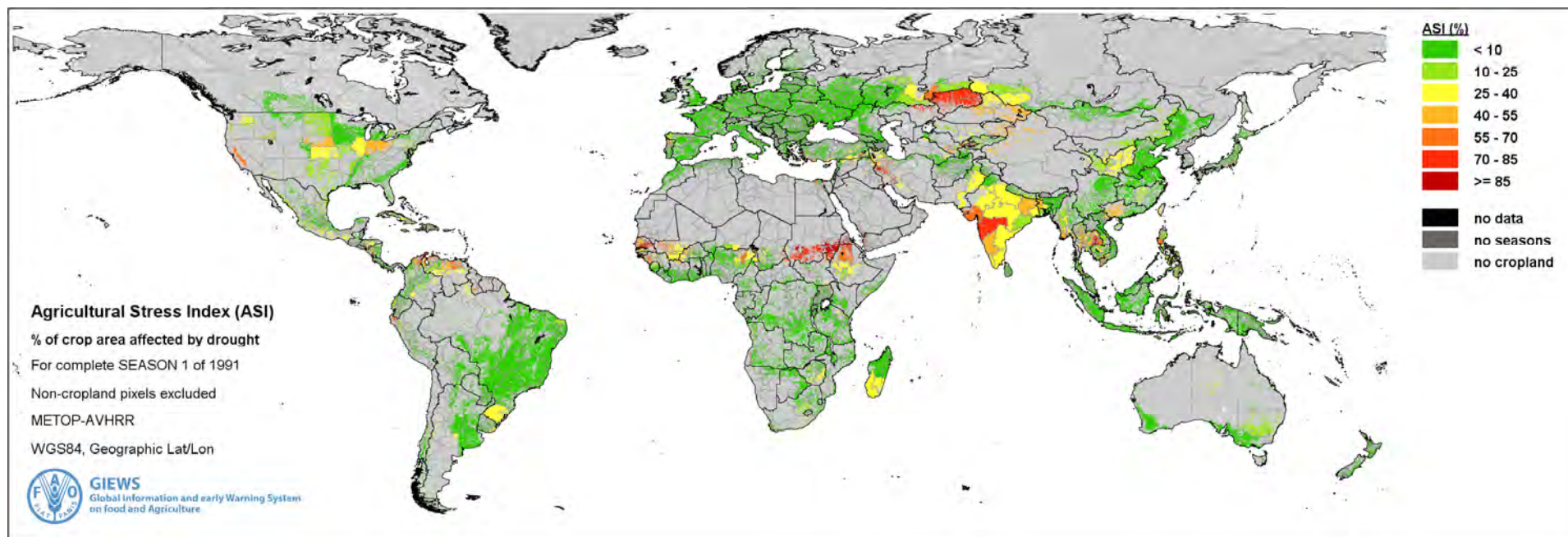
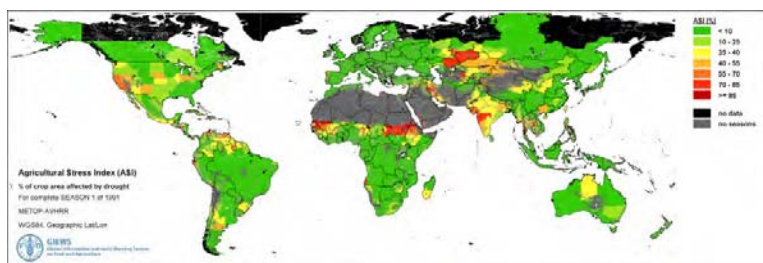


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1991

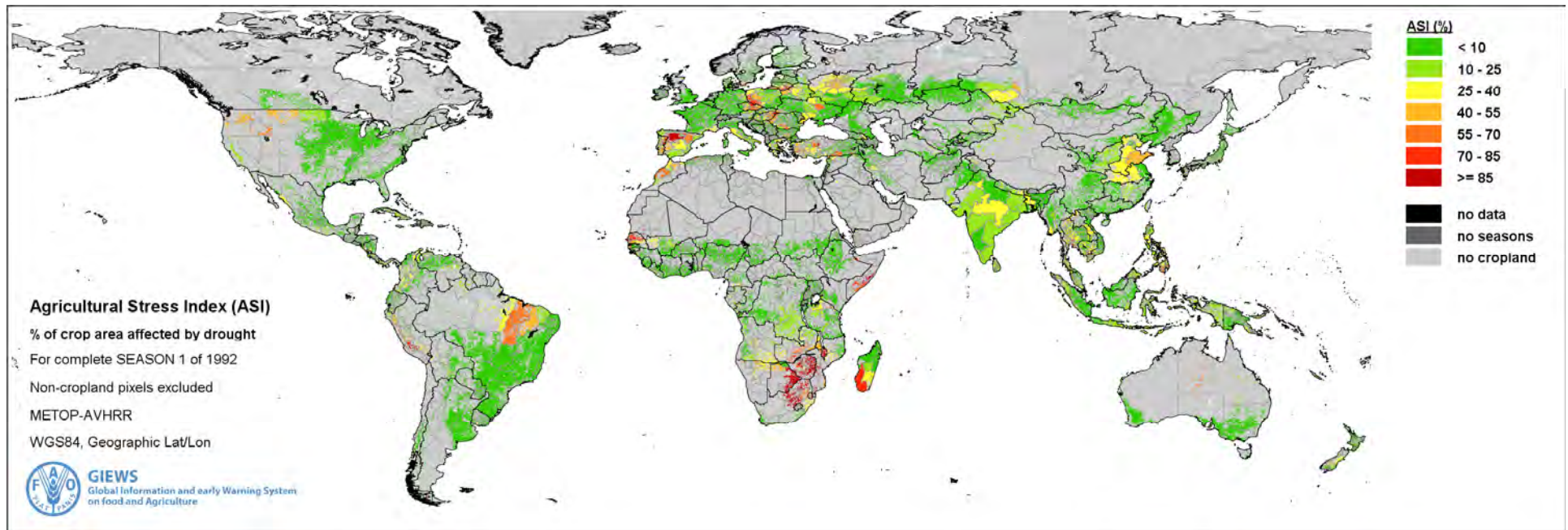
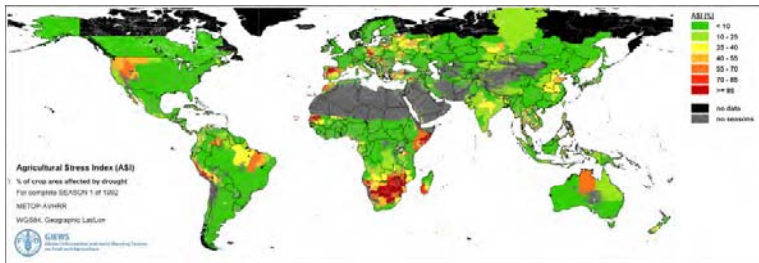


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1992

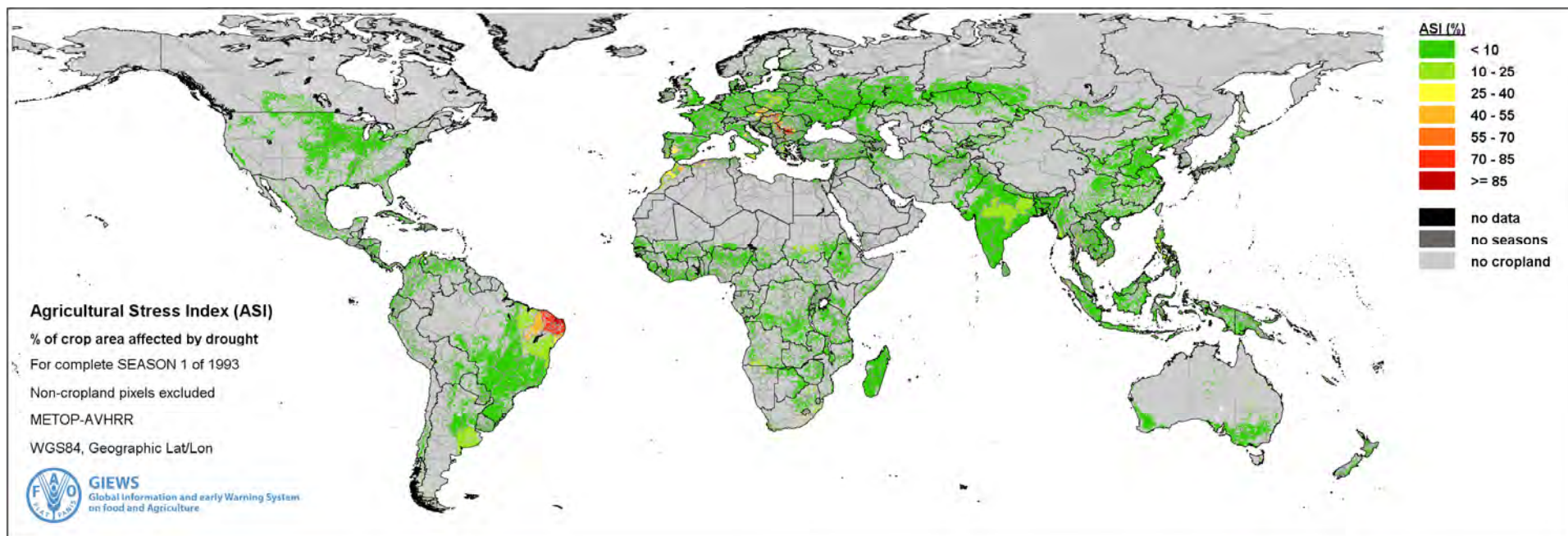
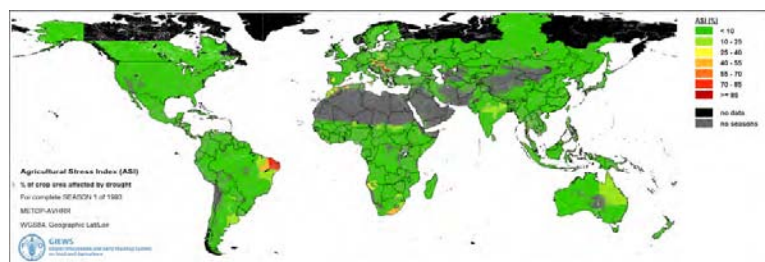


Southern Africa was severely affected by Drought due to the 1991/1992 ENSO phenomenon . **Australia:** A very severe drought occurred in the second half of 1991- which intensified in 1994 and 1995 to become the worst on record in [Queensland](#). This drought was influenced by a strong [El Nino](#) weather pattern and associated with high temperatures in July and August 1995, the fifth continuous year of drought in parts of Queensland



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1993

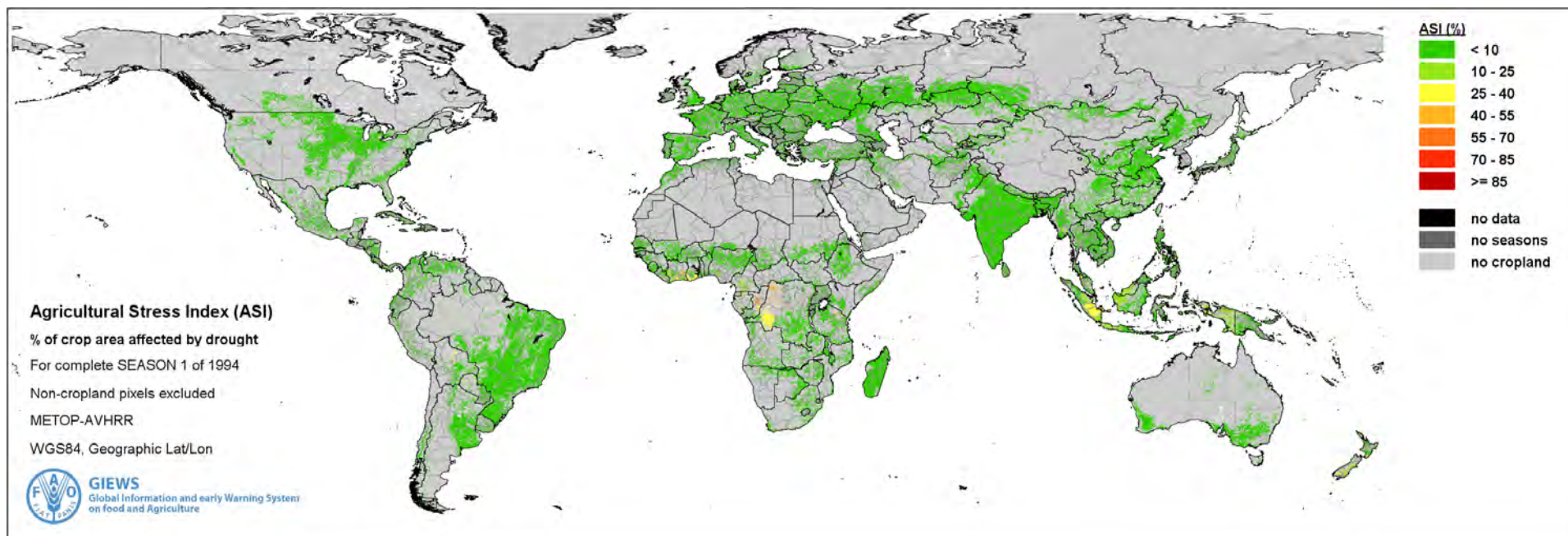
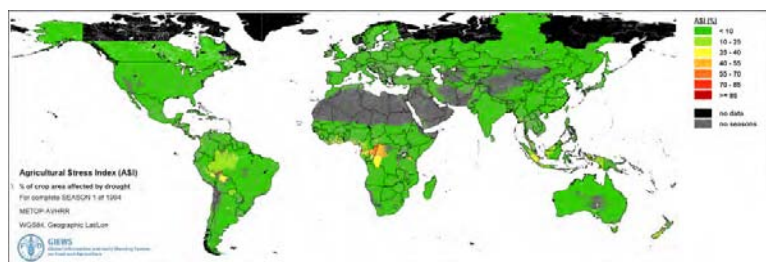


Brasil: In 1993 two million people, with probably another four to six million dependents, were employed on public works because of the lack of agricultural work after sugar cane harvests fell 50% in Pernambuco due to drought. By May 1993 the Marechal Puta dam had lost 54% of its total capacity of nearly 42 millions cubic meters (World Disasters Report: 1994).



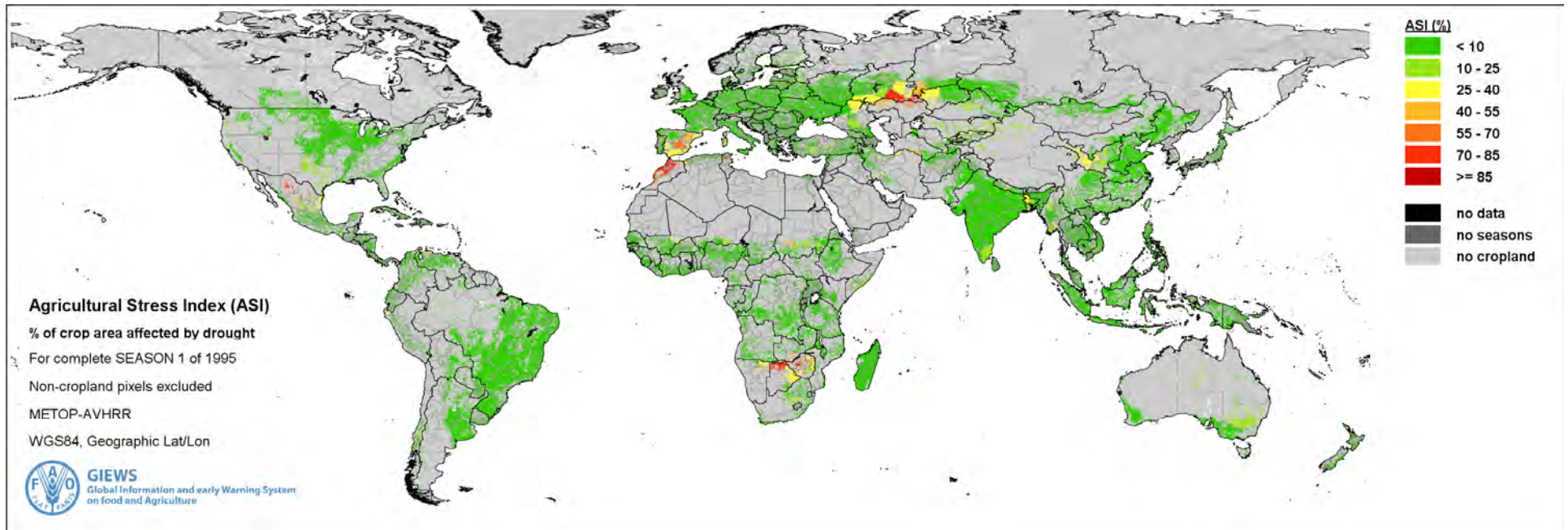
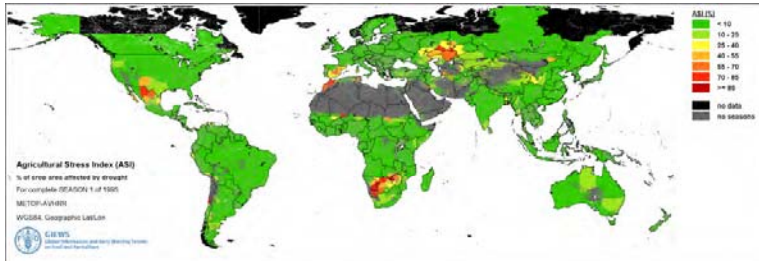
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1994



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1995

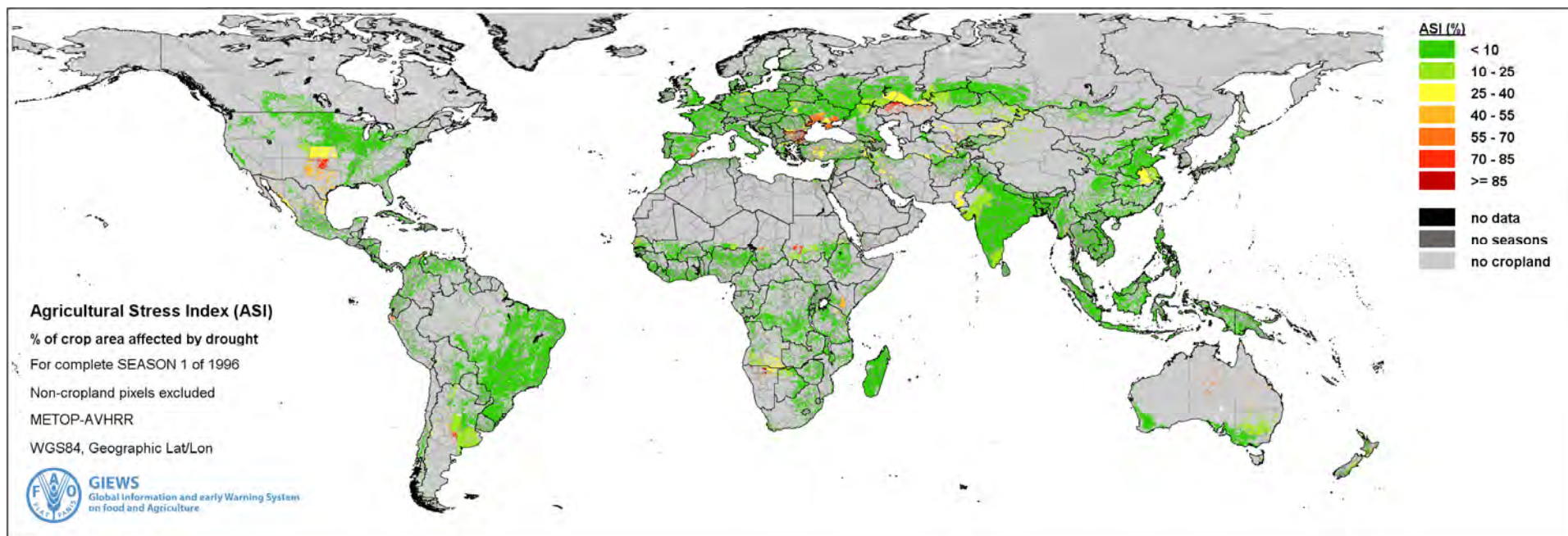
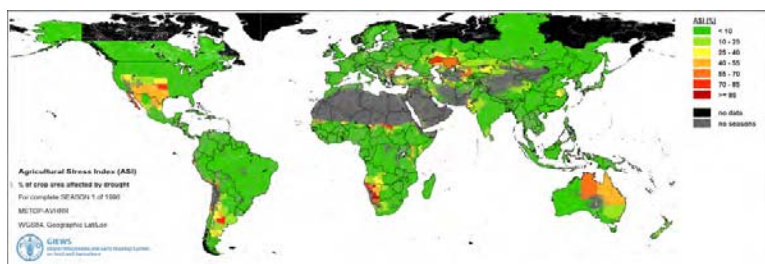


Morocco: Reduced incomes due to *drought* caused GDP to fall by 7.6% in **1995**, by 2.3% in 1997, and by 1.5% in 1999.



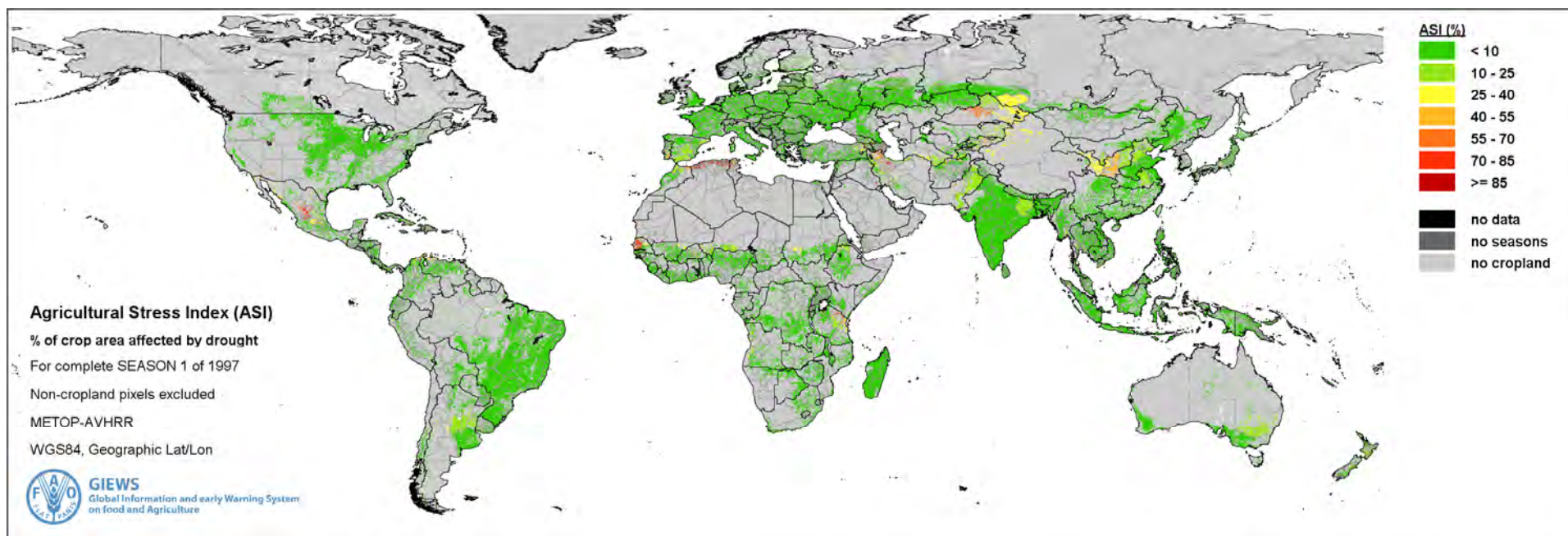
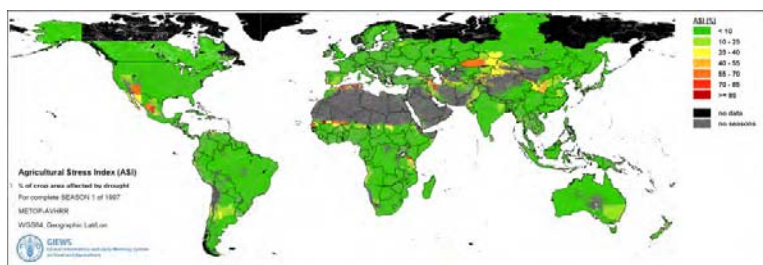
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1996



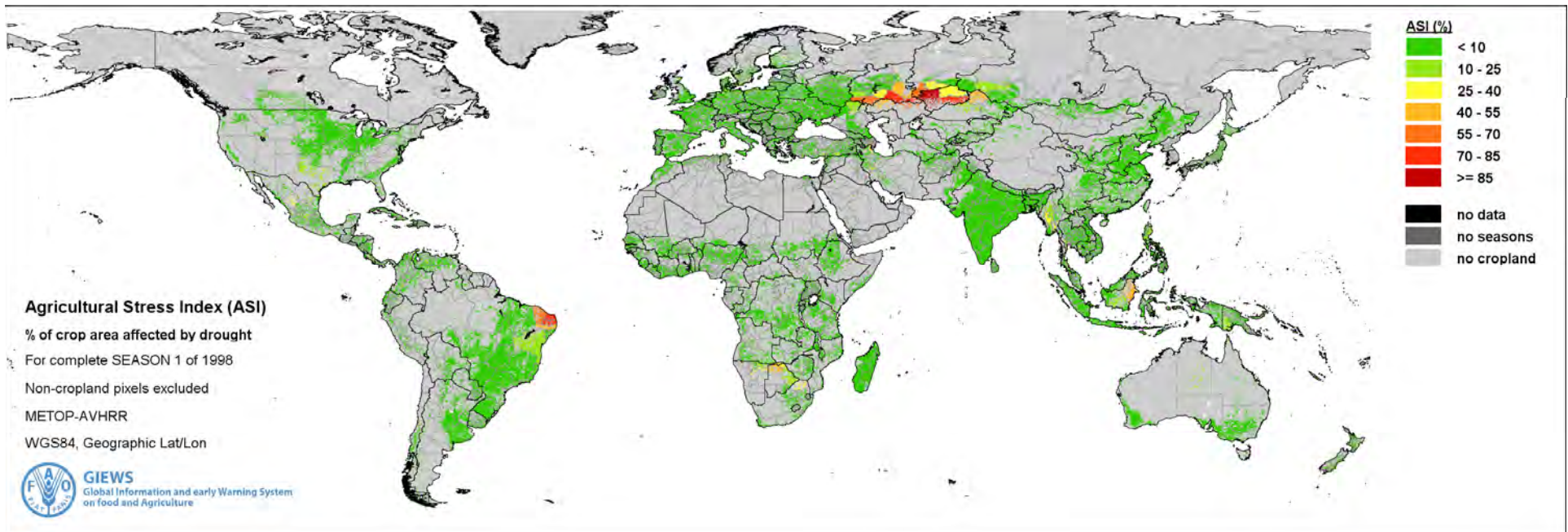
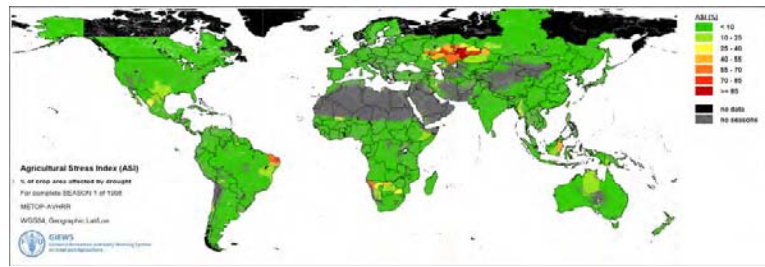
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1997



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1998

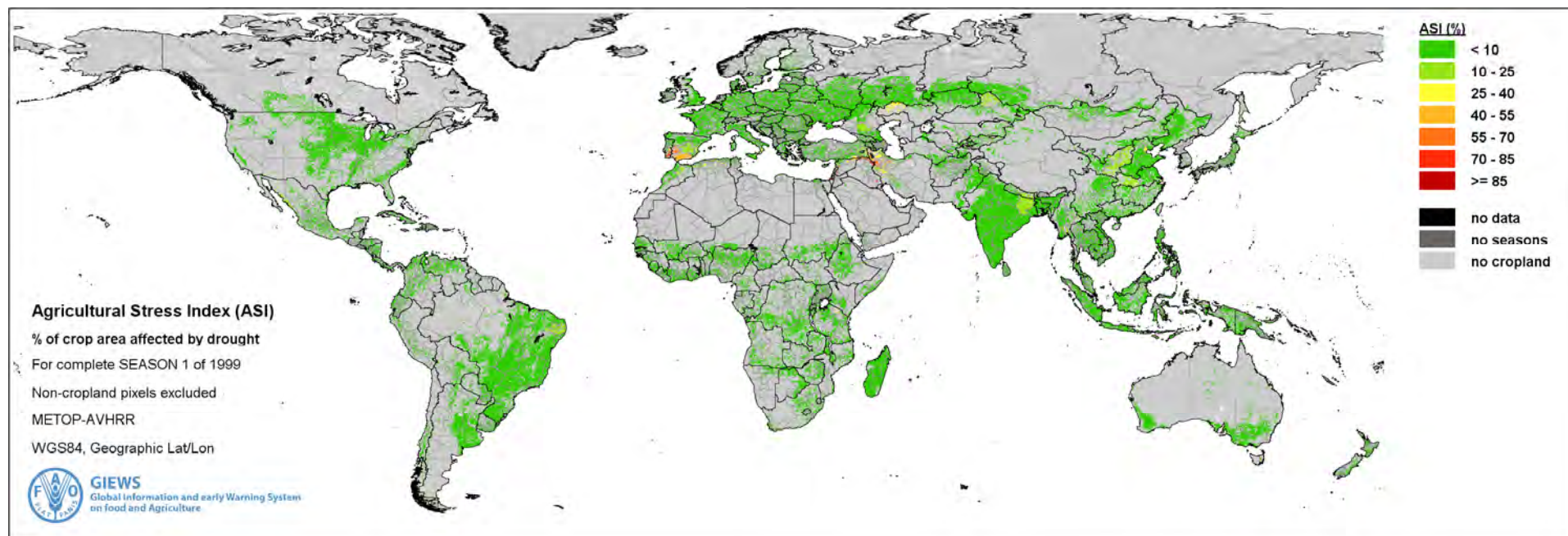
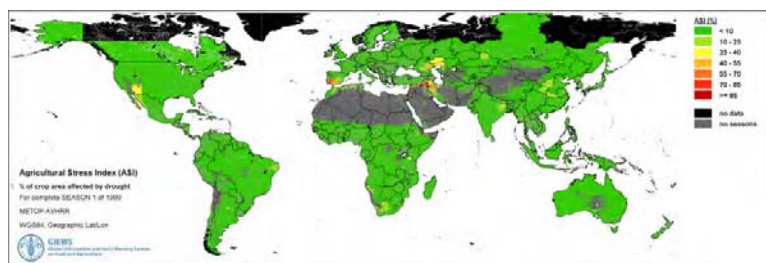


Russia: Severe drought in 1998-1999 led to a harvest of 48 million tons and 60.2 million tons respectively, adding more to the [economic crisis that hit Russia in 1998](#), and thus forcing Russia to accept [humanitarian aid](#) (source Wikipedia) **Brazil:** This season, probably as a consequence of El Niño phenomenon, rainfall has been insufficient or virtually non-existent in large areas of the states of Alagoas, Bahia, Ceará, Pernambuco, Piauí, Sergipe, Paraíba, Rio Grande do Norte, and the northern parts of Minas Gerais and Espírito Santo (GIEWS, 1998)



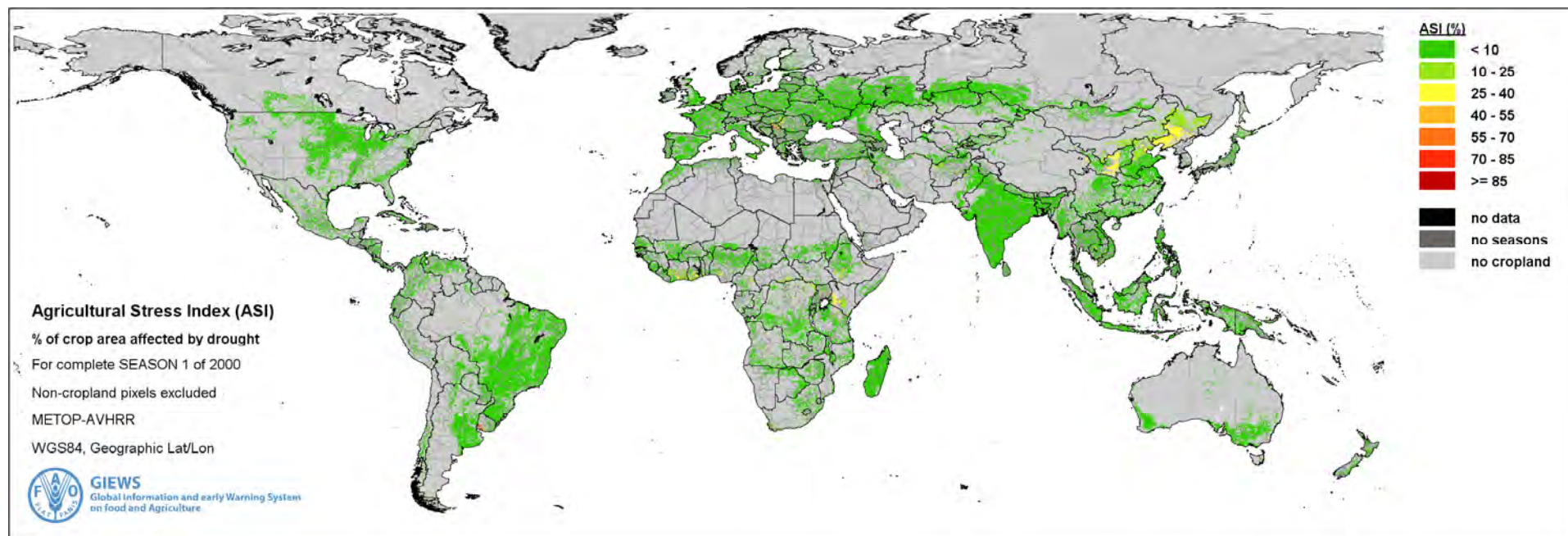
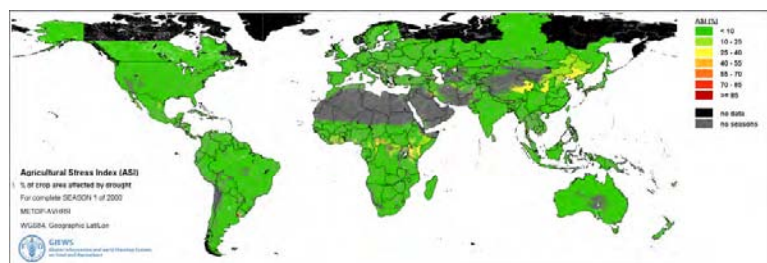
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1999



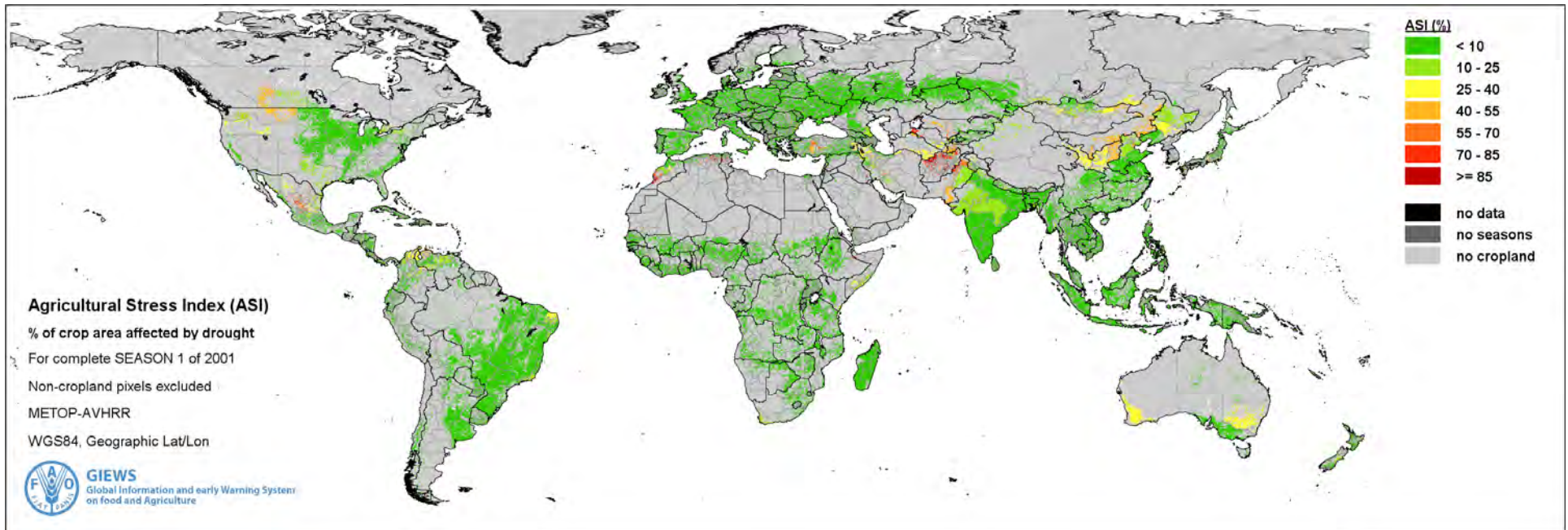
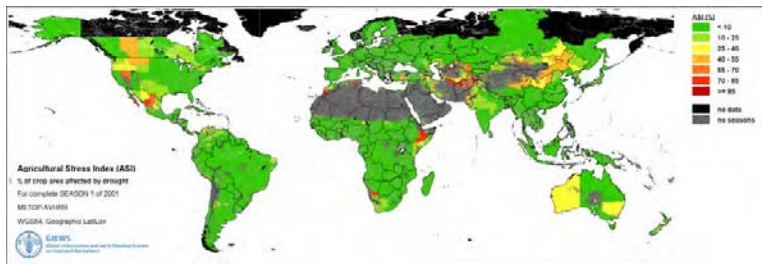
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2000



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2001

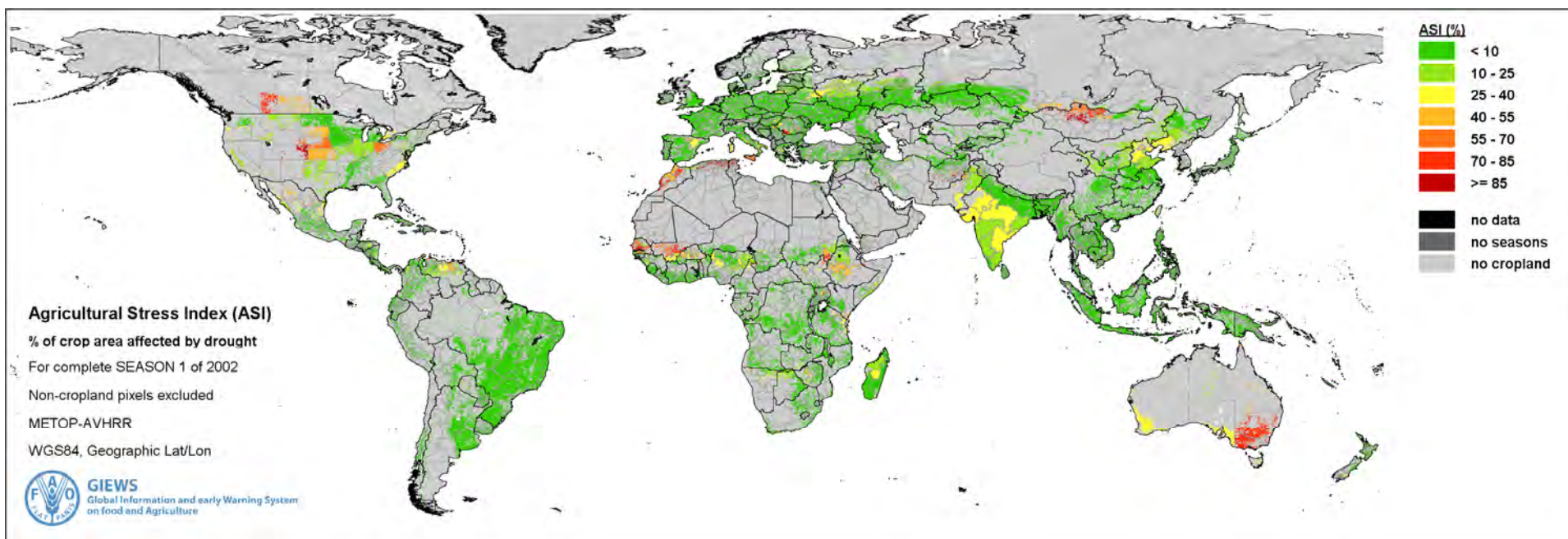
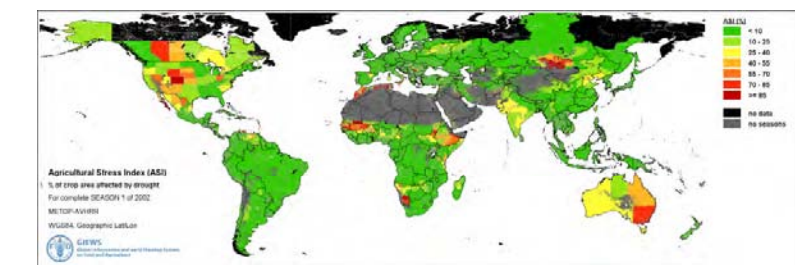


Afghanistan: Rain-fed crops failed in 2001, and irrigated agricultural output was reduced because of a lack of water and failure of infrastructure. Livestock heads were also reduced by 40% from 1998 to 2001.



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2002

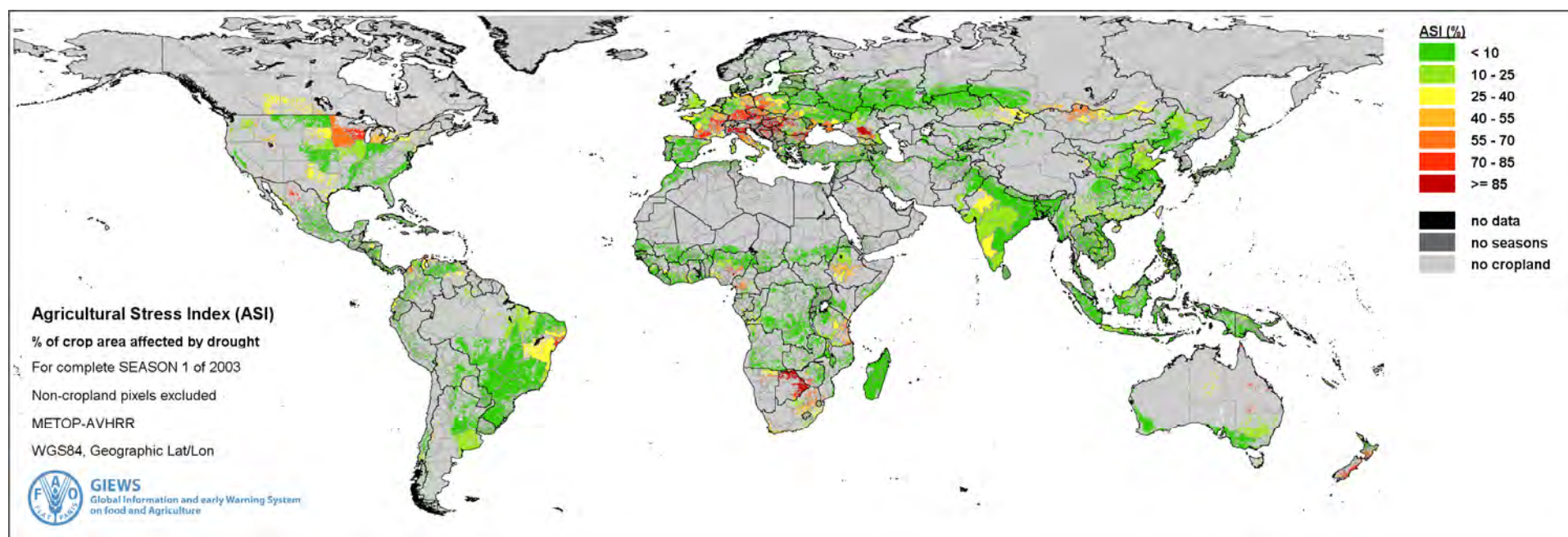
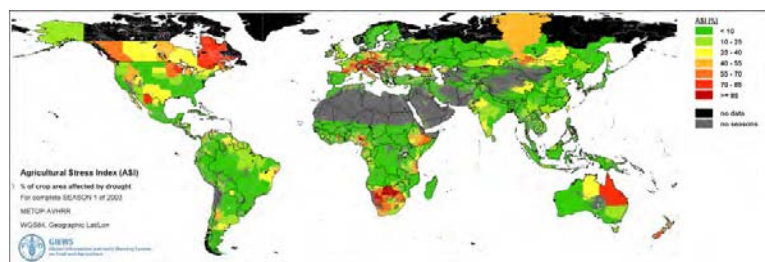


USA: The [Midwest](#) and [Rocky Mountains](#) became victims during 2002; the regions fell victim under exceptional drought which was accompanied by dry conditions, wildfires and hot temperatures over the [Western US](#) and Midwestern State areas. **Australian** annual rainfall data 1900-2004 shows clearly that the 2002 drought was just another cyclic drought.



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2003



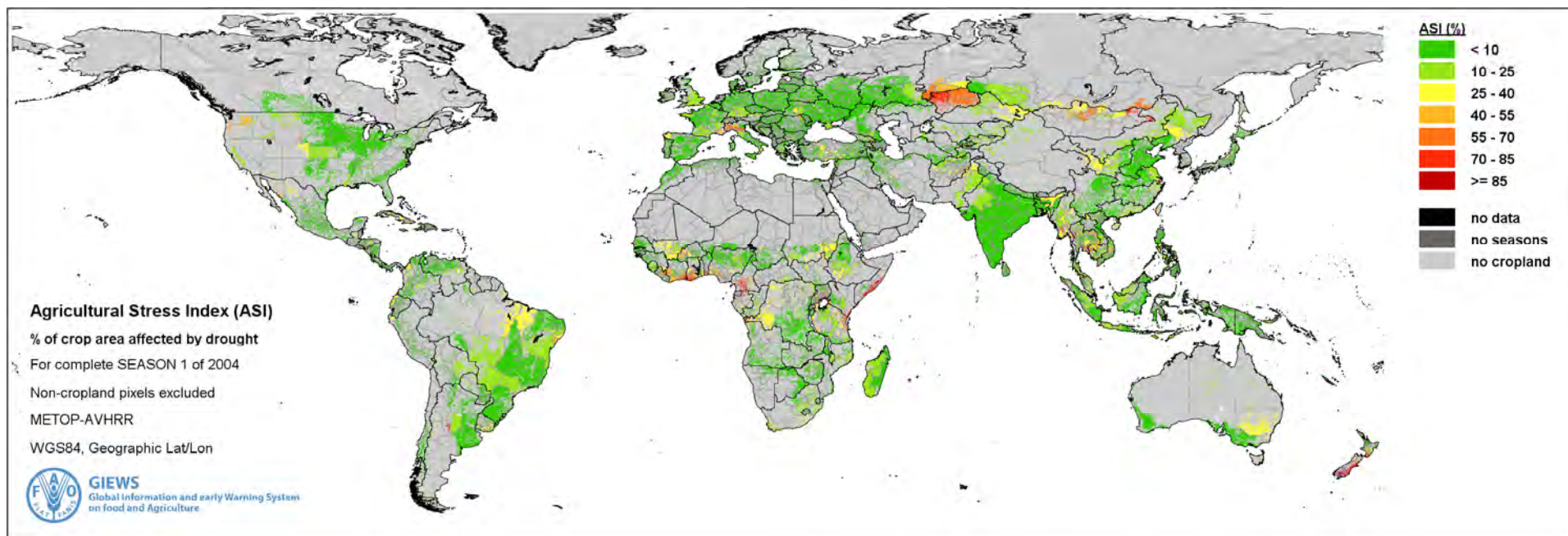
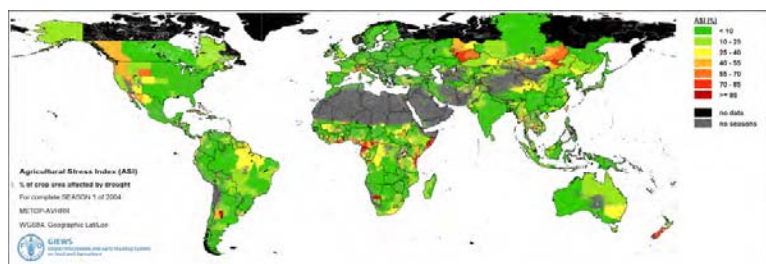
The **2003 European heat wave** was the hottest summer on record in Europe since at least 1540. **France** was hit especially hard. The heat wave led to health crises in several countries and combined with drought to create a [crop](#) shortfall in parts of Southern Europe. Peer reviewed analysis places the European death toll at 70,000.^[2]

Botswana : The 2003 coarse grain production, mainly sorghum, is forecast to be sharply reduced due to dry weather **South Africa**: In October 2003, the South African government approved an allocation of ZAR 250 million² for drought relief **Mexico**: Sequía en Chihuahua podría suspender suministro para riego en 2003 **New Zealand**: NZ Herald 29.05.2003 A farming slump has wiped more than \$1 billion off New Zealand's gross domestic product. The Ministry of Agriculture and Forestry estimates that agriculture's contribution to GDP fell 15 per cent to \$7.97 billion in the year to March. A cold spring and summer drought - yet to break in parts of the lower North Island



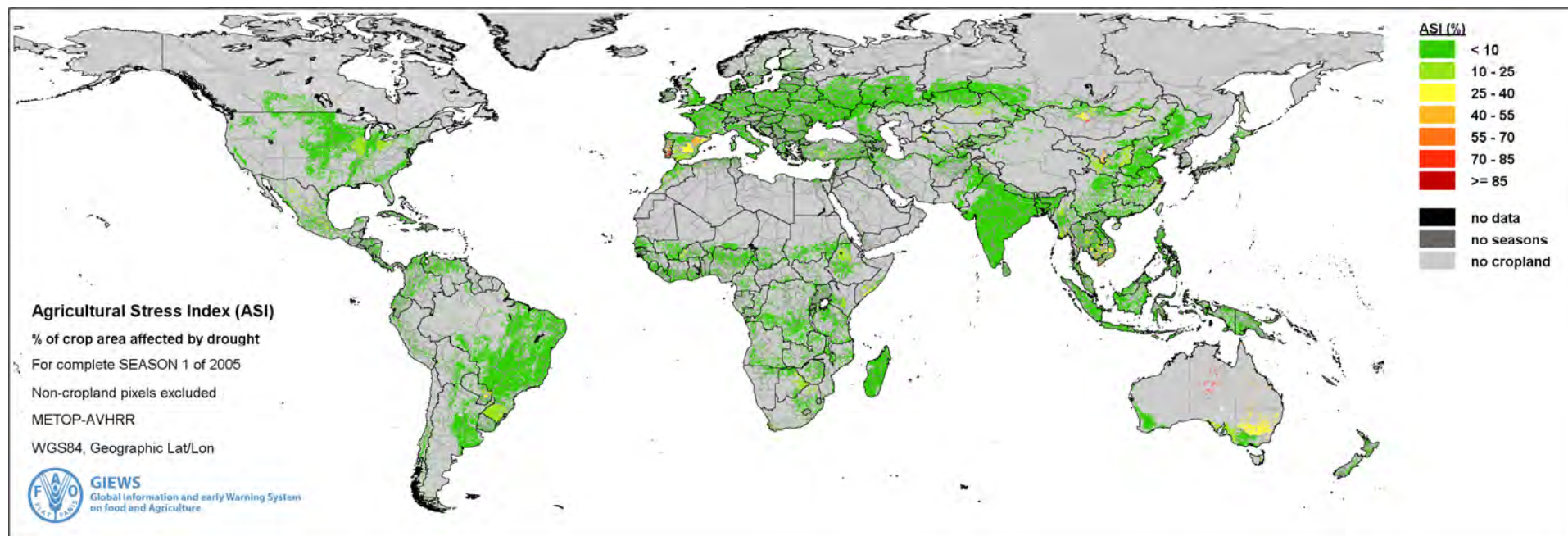
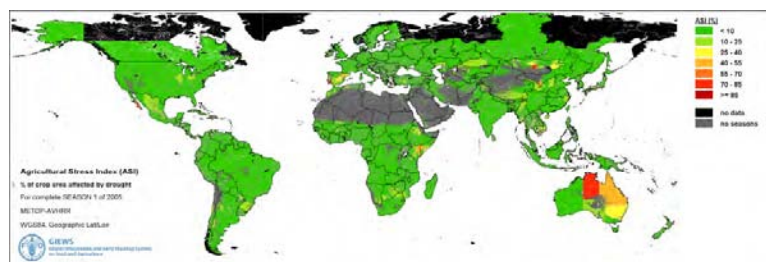
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2004



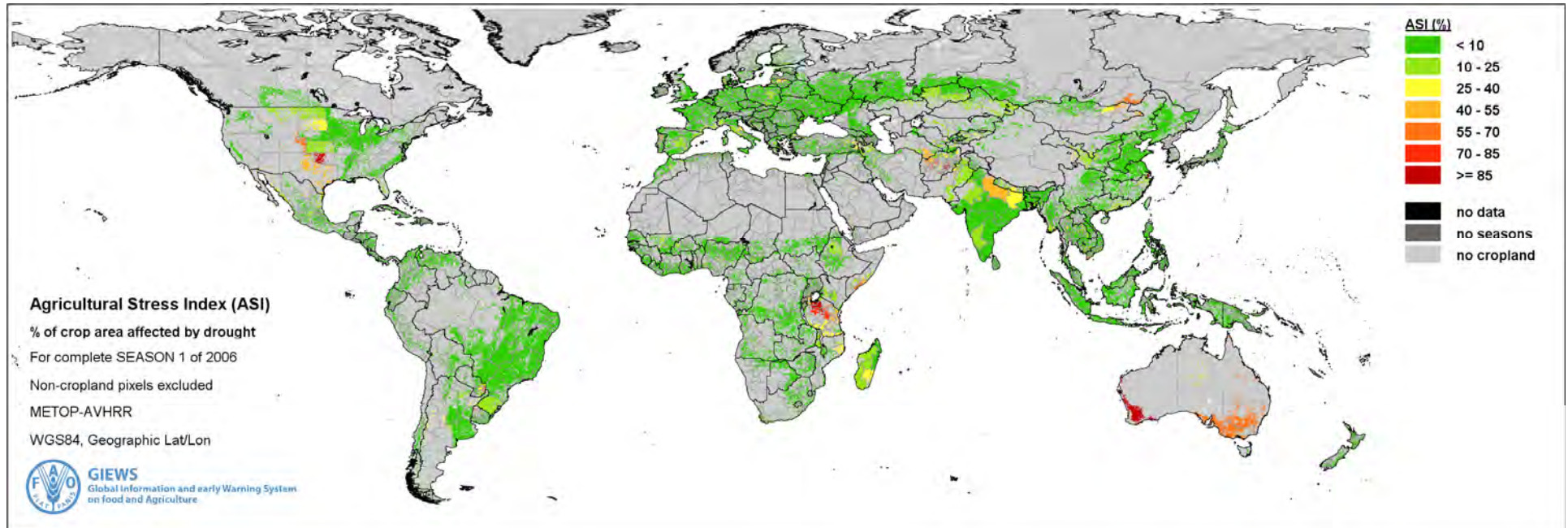
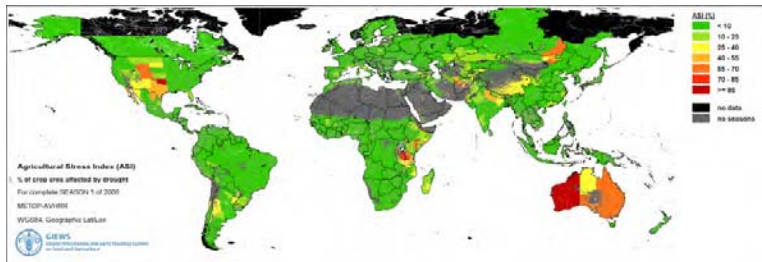
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2005



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2006

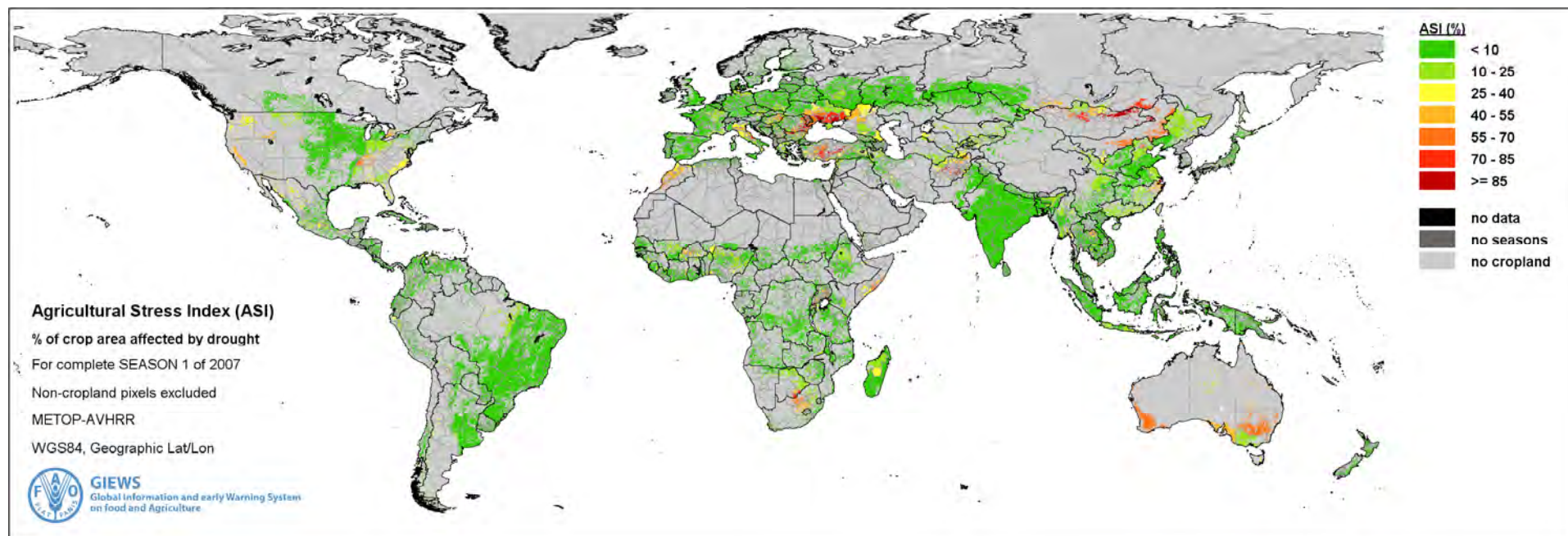
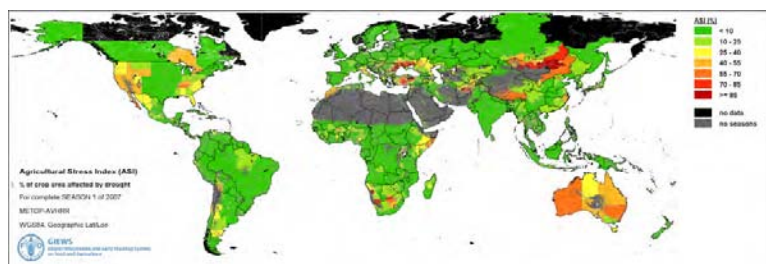


Most **Australian** mainland capital cities are facing a major water crisis with less than 50% of water storages remaining. For example, Melbourne has had rain up to 90% below the average for September and October 2006, compounding the problem of extremely low rainfall from the preceding winter months. **Tanzania:** WFP today urgently appealed for US\$16.6 million to feed 565,000 people in Tanzania facing severe hunger because of drought



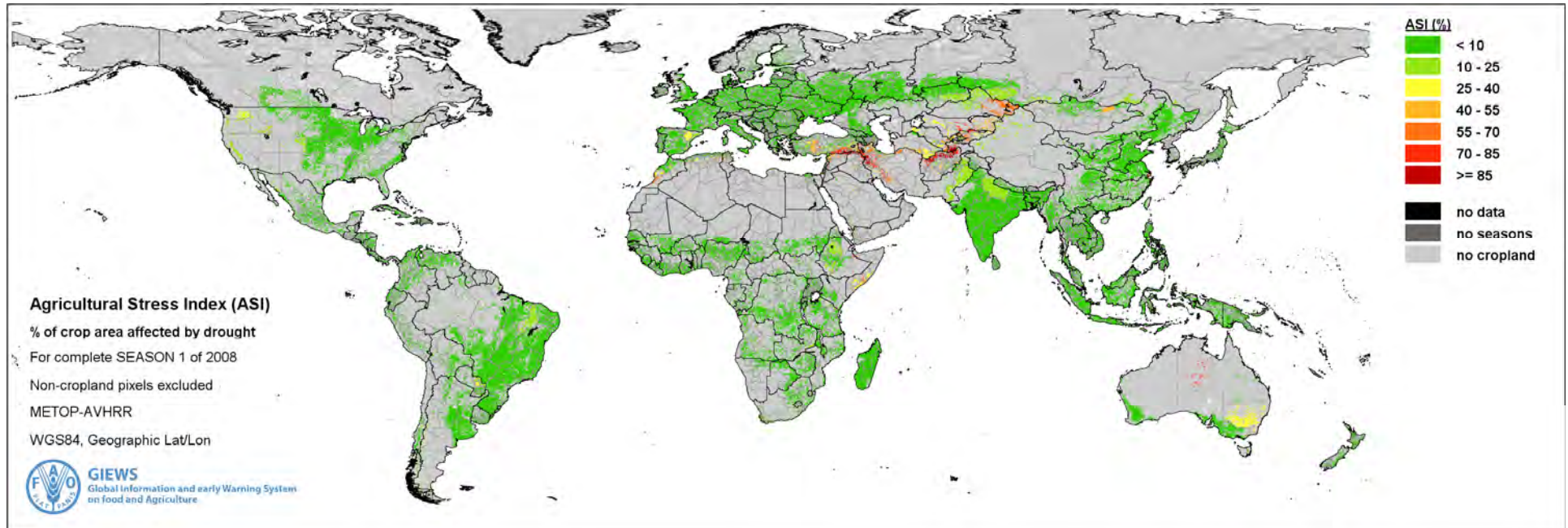
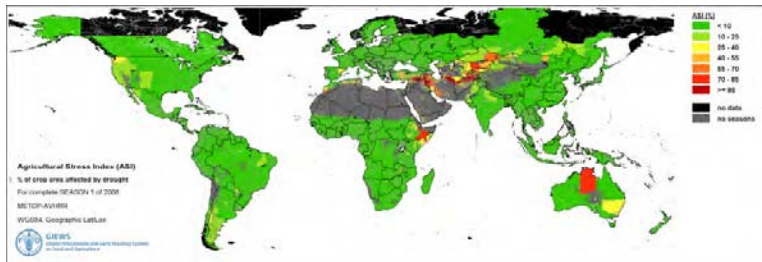
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2007



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2008

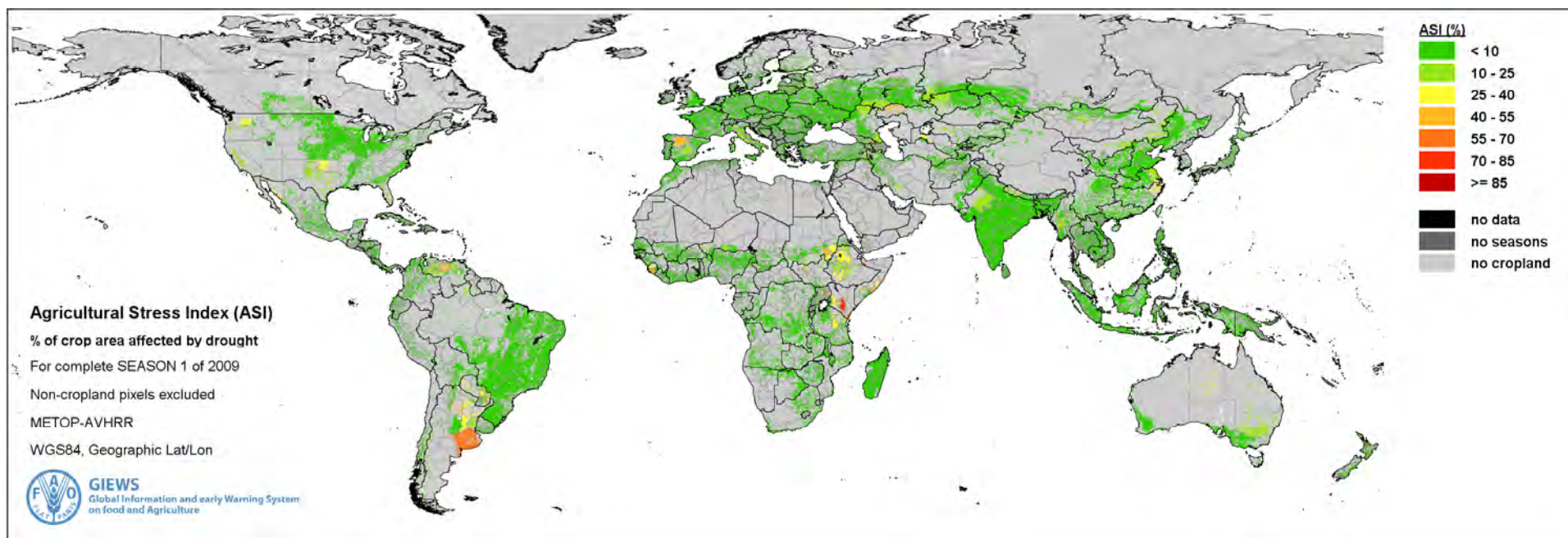
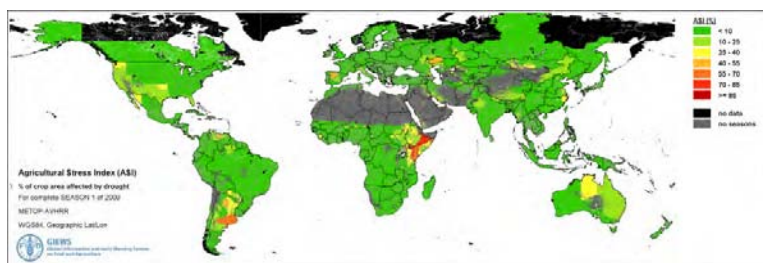


Iran: Approximately 6 million tons of wheat will be purchased from 15 countries in 2009 because of the [drought](#) in **2008**, thus making Iran the largest wheat importer in the world.



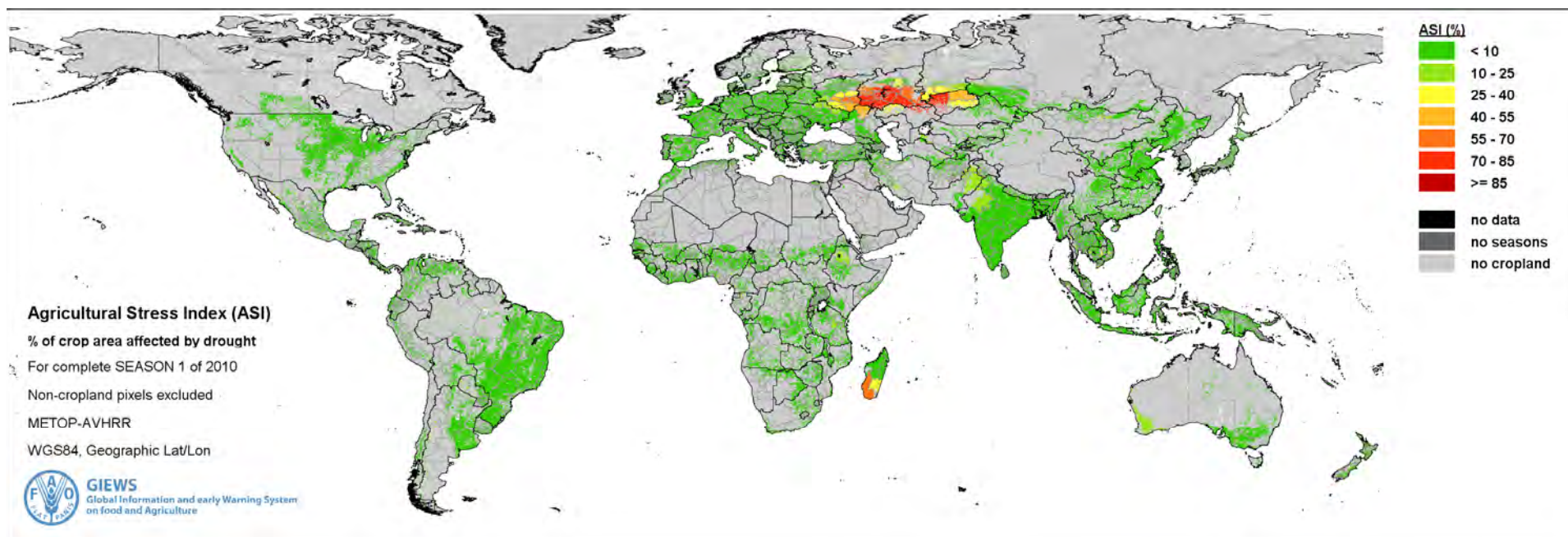
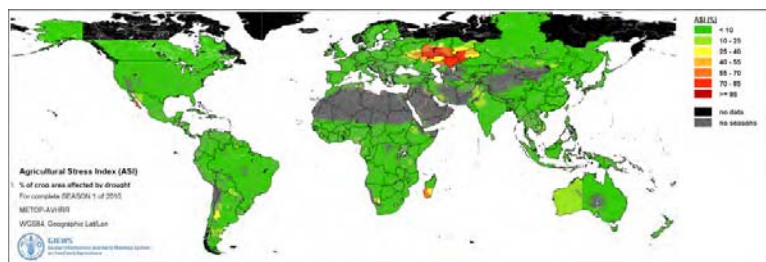
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2009



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2010

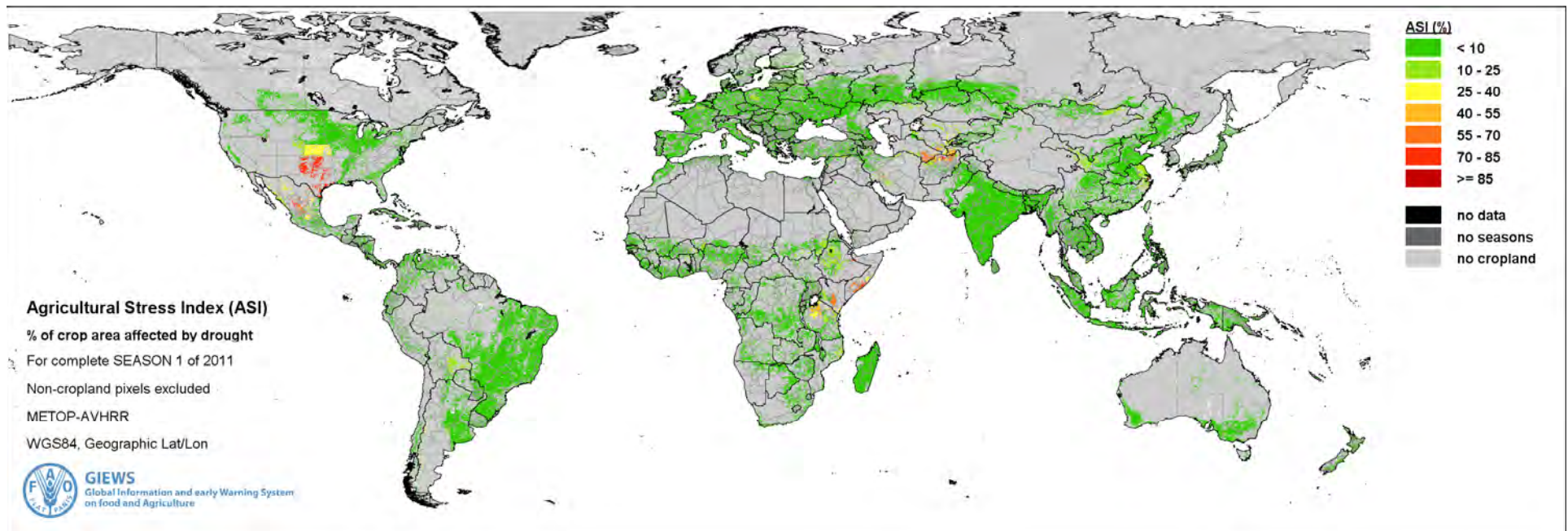
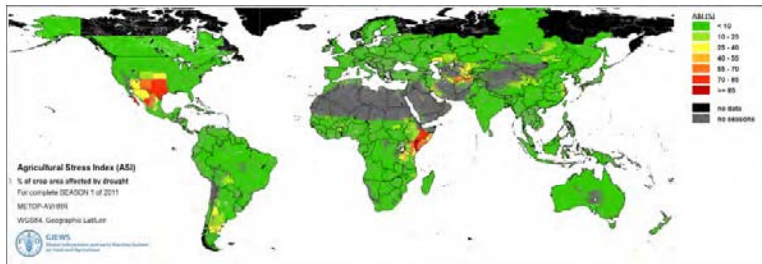


Russia has been gripped in a severe drought from July 2010, which may see grain production fall by 20-25.



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2011

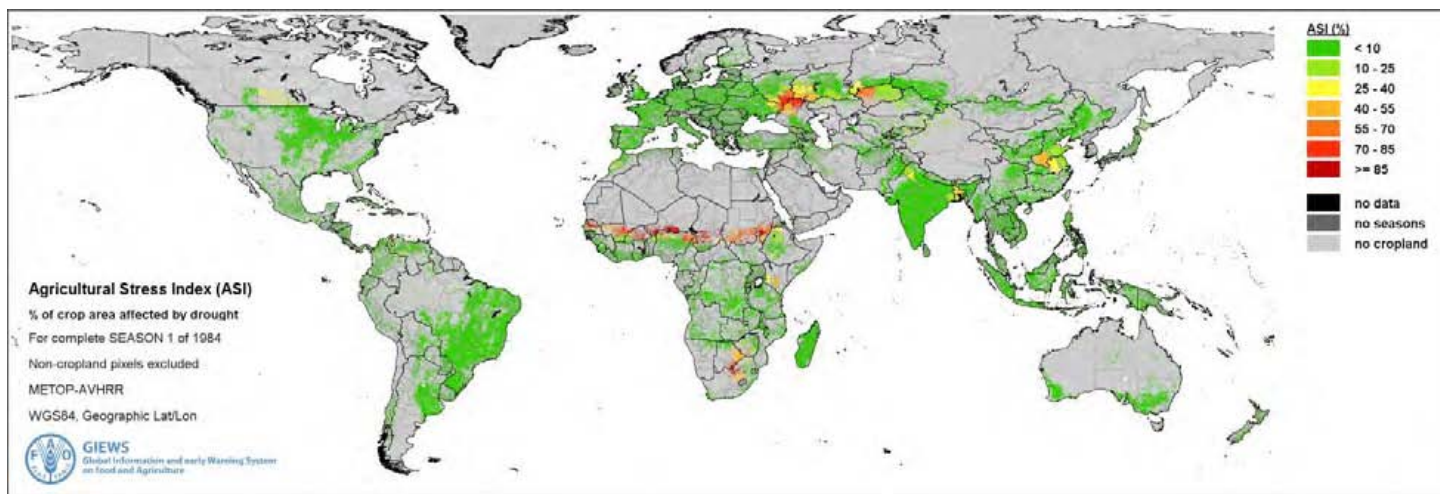
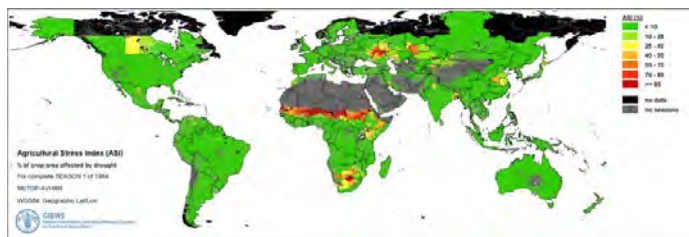


Eastern Africa: Since mid-July 2011, a severe [drought](#) has been affecting the entire [East Africa](#) region.^[6] Said to be "the worst in 60 years",^[7] the drought has caused a severe [food crisis](#) across [Somalia](#), [Djibouti](#), [Ethiopia](#) and [Kenya](#) that threatens the livelihood of 9.5 million people. **United States:** Much of Texas is bone dry, with scarcely any moisture to be found in the top layers of soil. Grass is so dry it crunches underfoot in many places. The nation's leading cattle-producing state just endured its driest seven-month span on record, and some ranchers are culling their herds to avoid paying supplemental feed costs. **Mexico:** Mexico is being battered its worst drought in seven decades, which has devastated farm life and is expected to continue into next year. The lack of rainfall has affected almost 70 percent of the country and northern states like Coahuila, San Luis Potosi, Sonora, Tamaulipas and Zacatecas have suffered the most acute water shortage.



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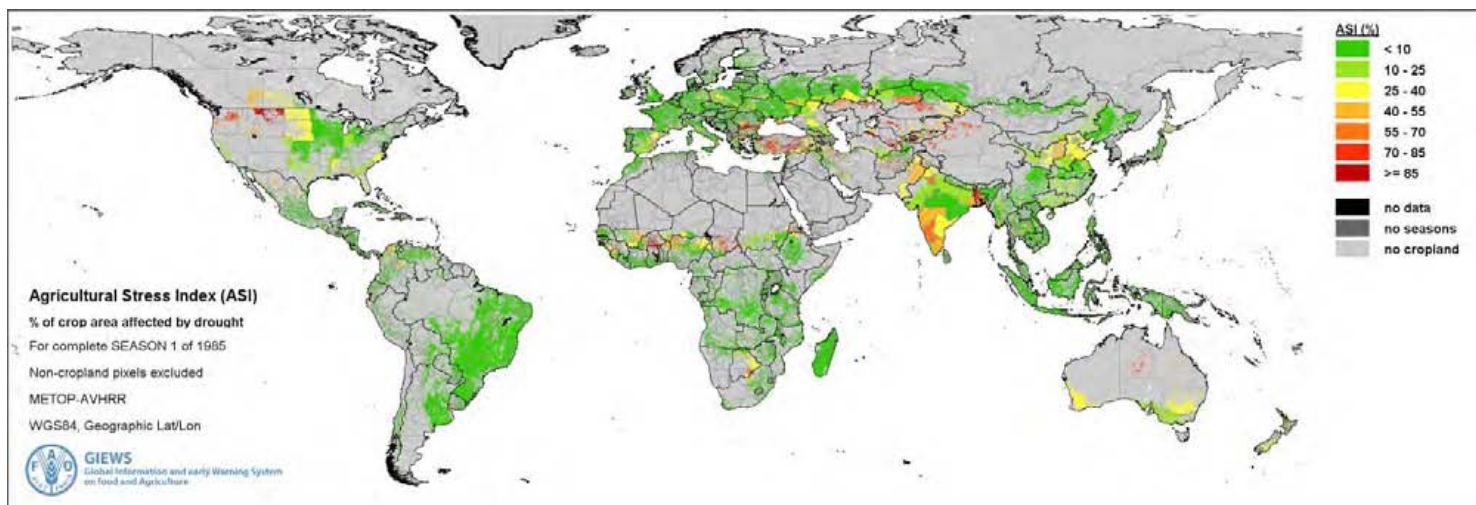
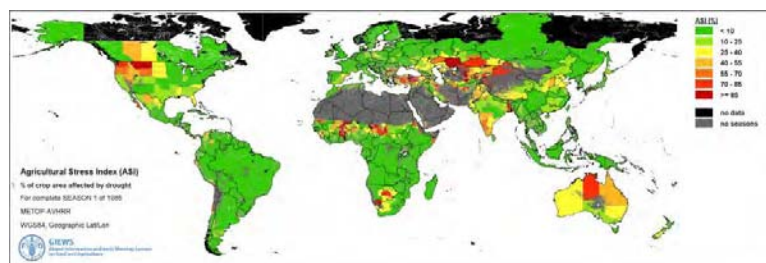
1984



Africa: 1981 – 1984. During the crisis, an astounding 20 nations of Africa were under severe drought. Entire rivers and lakes completely dried up. Up to 20,000 people starved to death each month. Although the total number of people who perished is not completely known, it is estimated that over 1 million people died as a direct result of the drought. **Sahel:** The worst drought in the Sahel during the early-mid 1980's occurred the year 1984 affecting most Sahel countries. **Botswana:** It is a country that is prone to drought. Since independence, drought has occurred in the following years: 1968-70; 1974-75; 1979-80: **1981-87:** 1990-92.



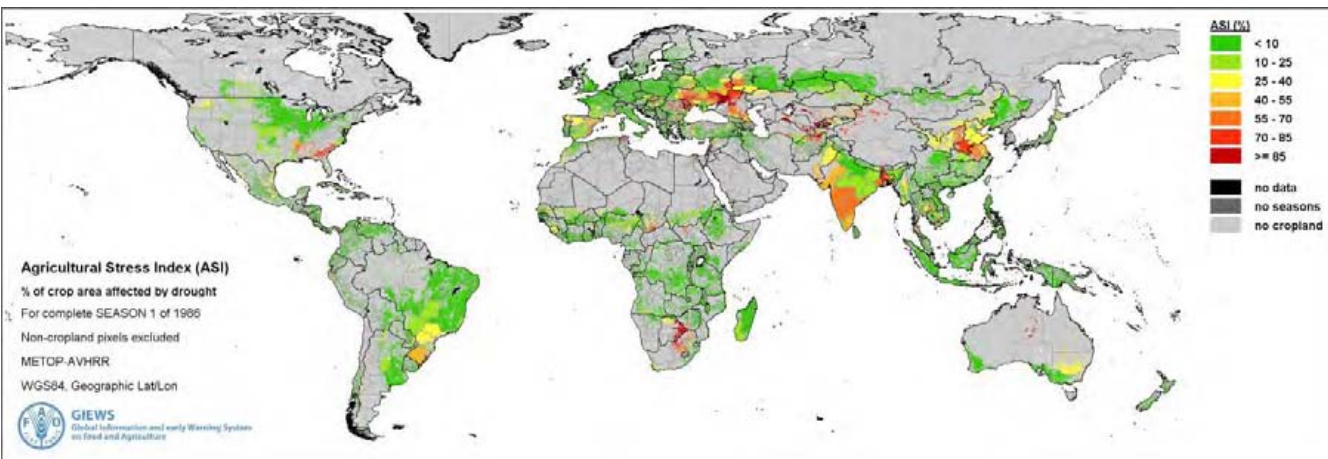
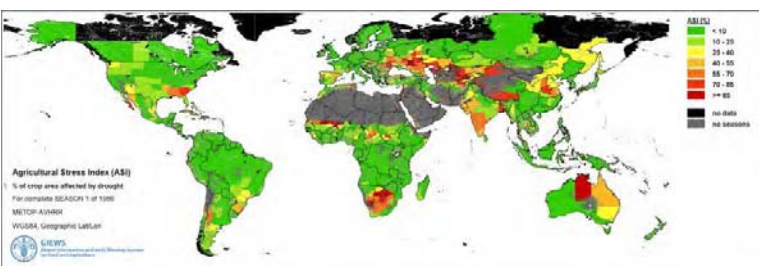
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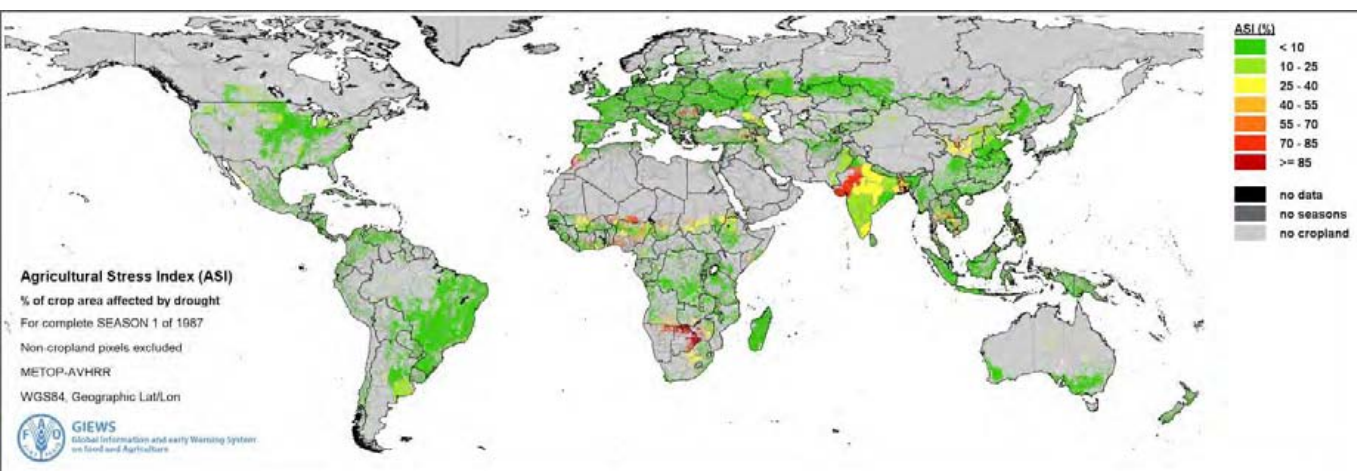
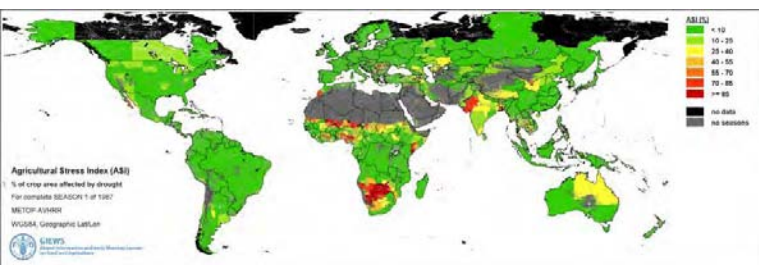
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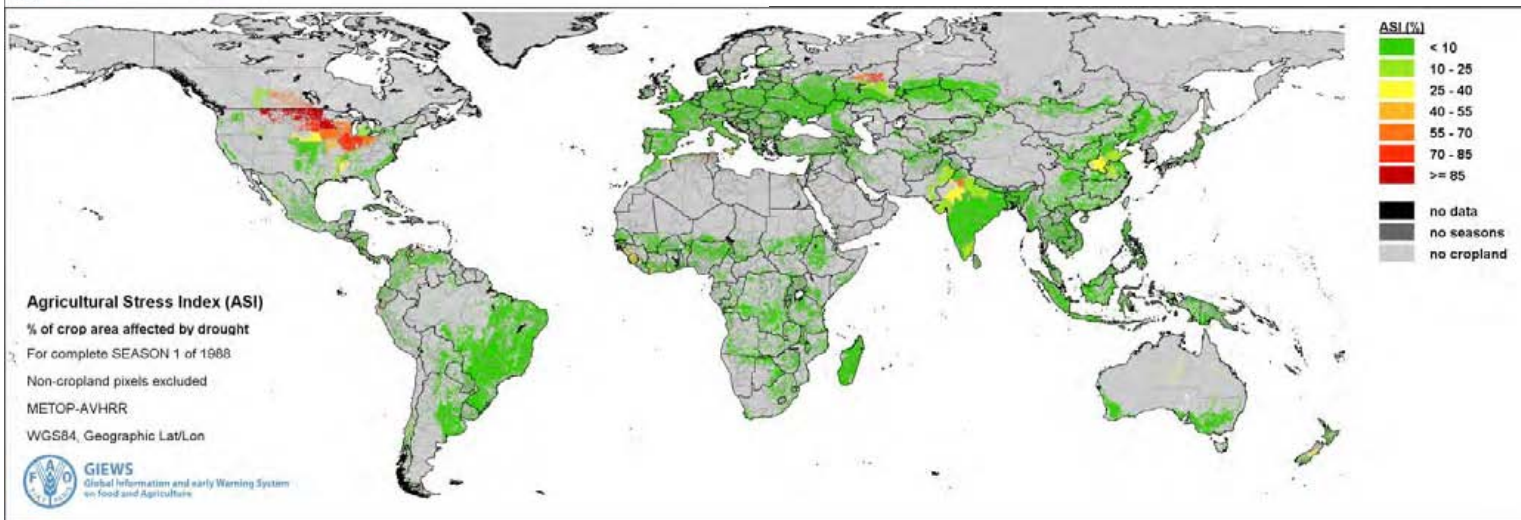
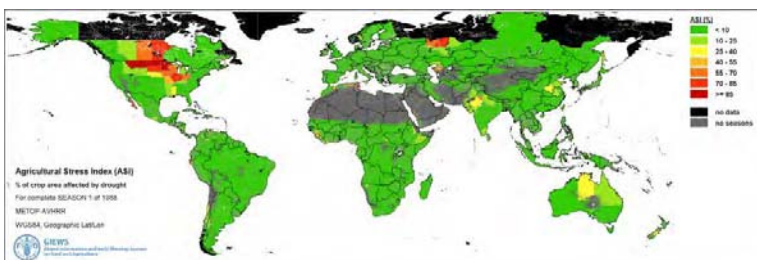
1987



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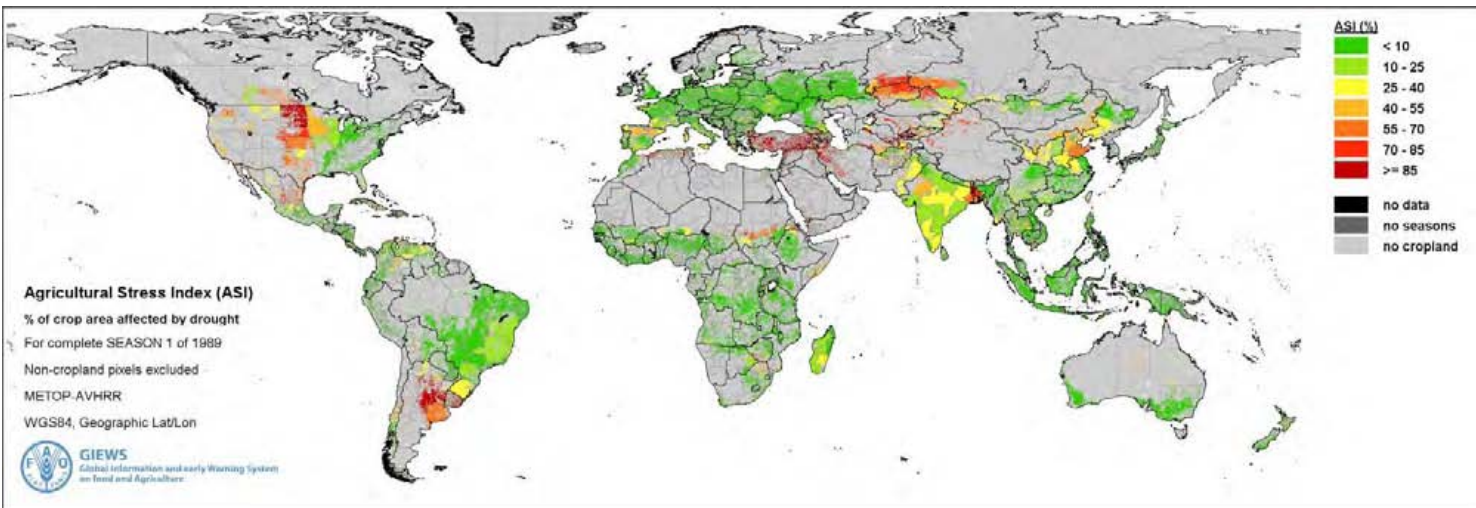
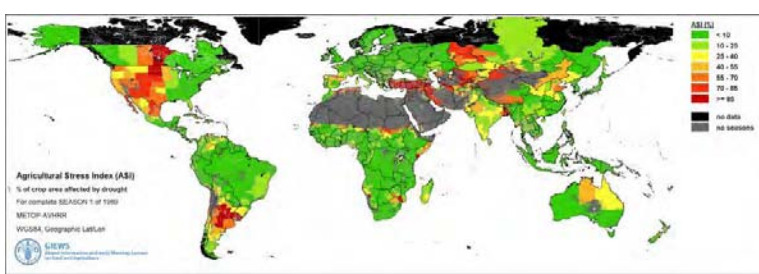
1988



USA Another significant drought in the United States occurred during 1988 and 1989. Following a milder drought in the [Southeastern United States](#) and California the year before, this drought spread from the [Mid-Atlantic](#), Southeast, [Midwest](#), Northern Great Plains and [Western United States](#). This drought was widespread, unusually intense and accompanied by heat waves which killed around 4800 to 17000 people across the United States and also killed livestock across the United States. One particular reason that the Drought of 1988 became very damaging was farmers might have farmed on land which was marginally arable. Another reason was pumping [groundwater](#) near the depletion mark. The [Drought of 1988](#) destroyed crops almost nationwide, residents' lawns went brown and water restrictions were declared many cities. This drought was very catastrophic for multiple reasons; it continued across the Upper Midwest States and North Plains States during 1989, not officially ending until 1990.[28] The drought also affected **Canada** in certain divisions.



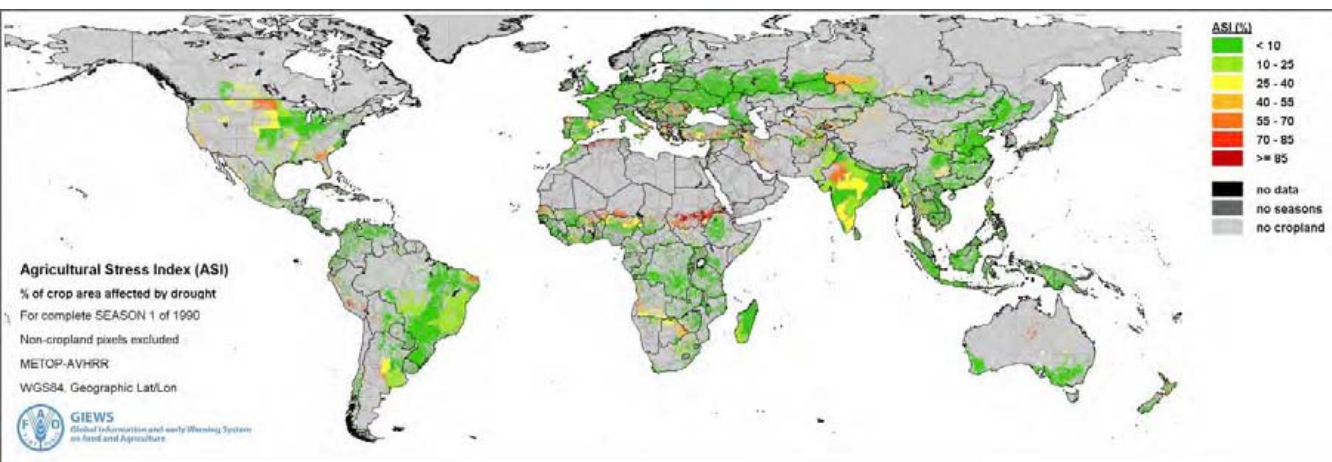
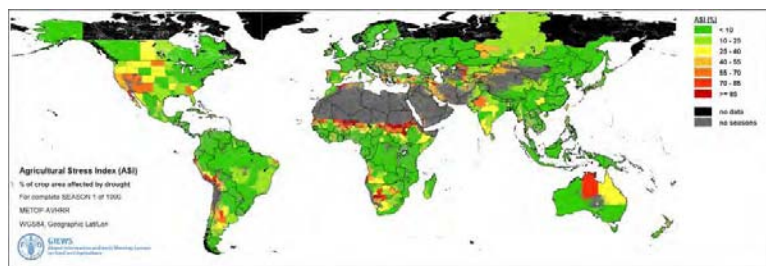
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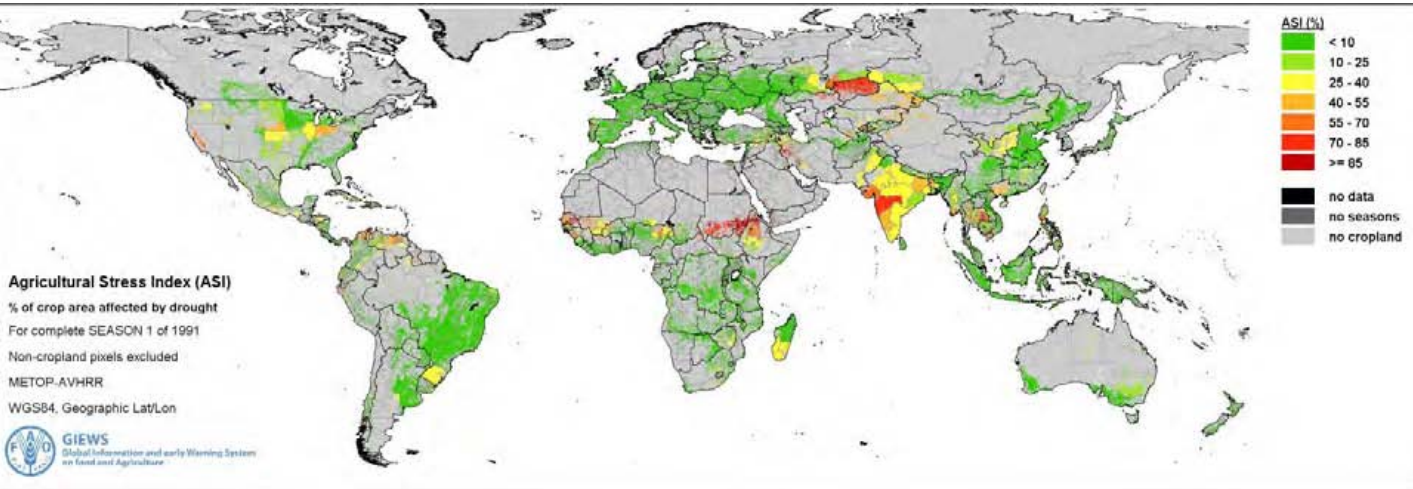
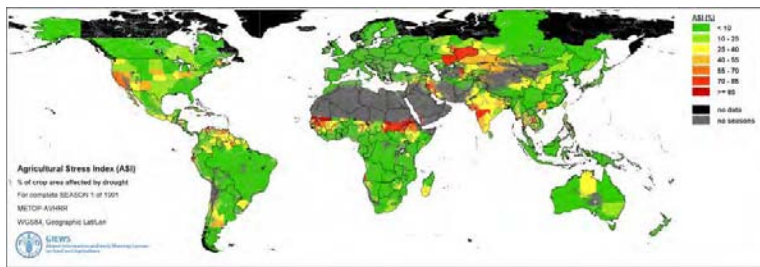
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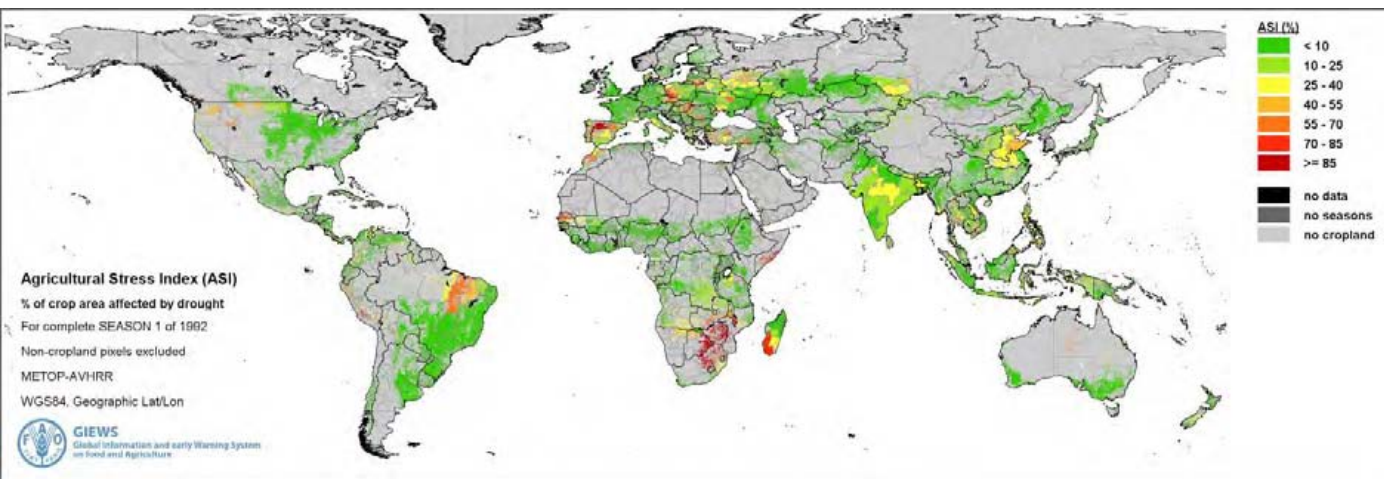
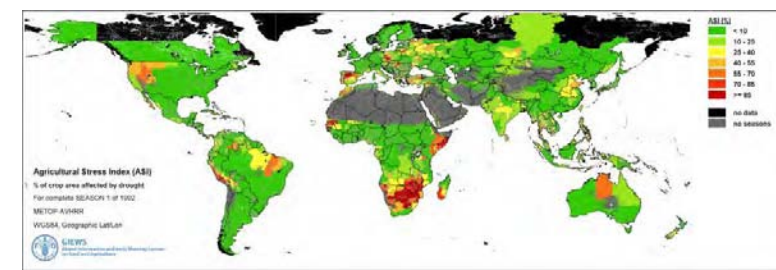


1991



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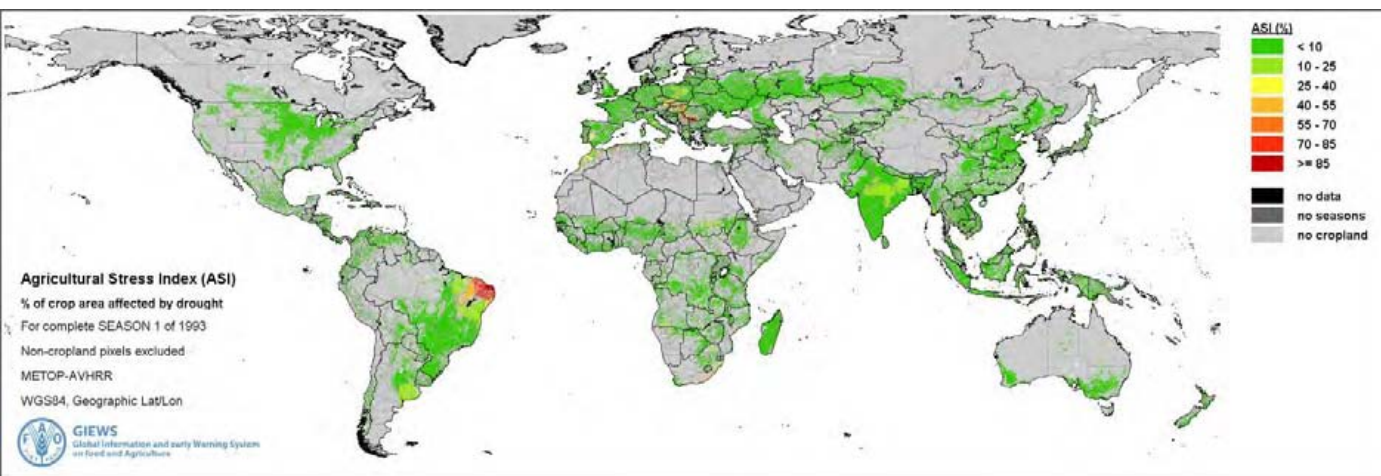
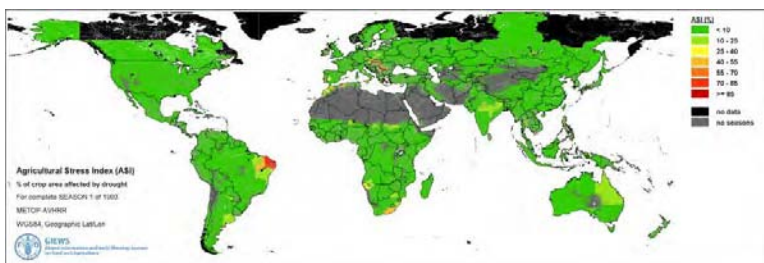
1992



Southern Africa was severely affected by Drought due to the 1991/1992 ENSO phenomenon . **Australia:** A very severe drought occurred in the second half of 1991· which intensified in 1994 and 1995 to become the worst on record in [Queensland](#). This drought was influenced by a strong [El Nino](#) weather pattern and associated with high temperatures in July and August 1995, the fifth continuous year of drought in parts of Queensland



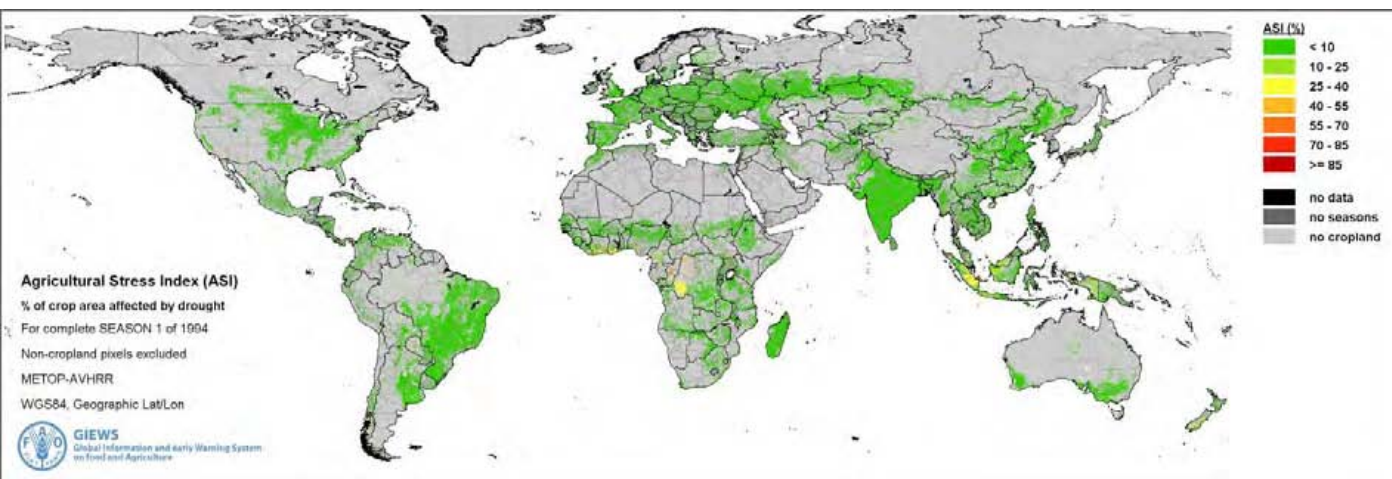
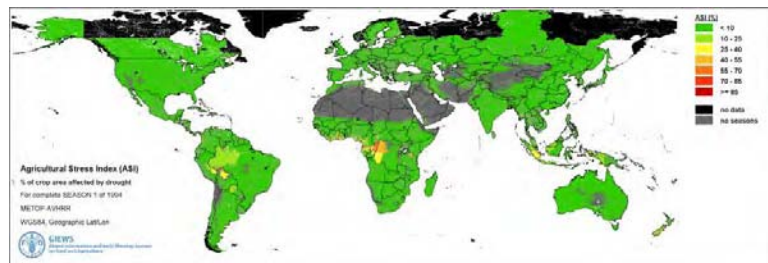
1993



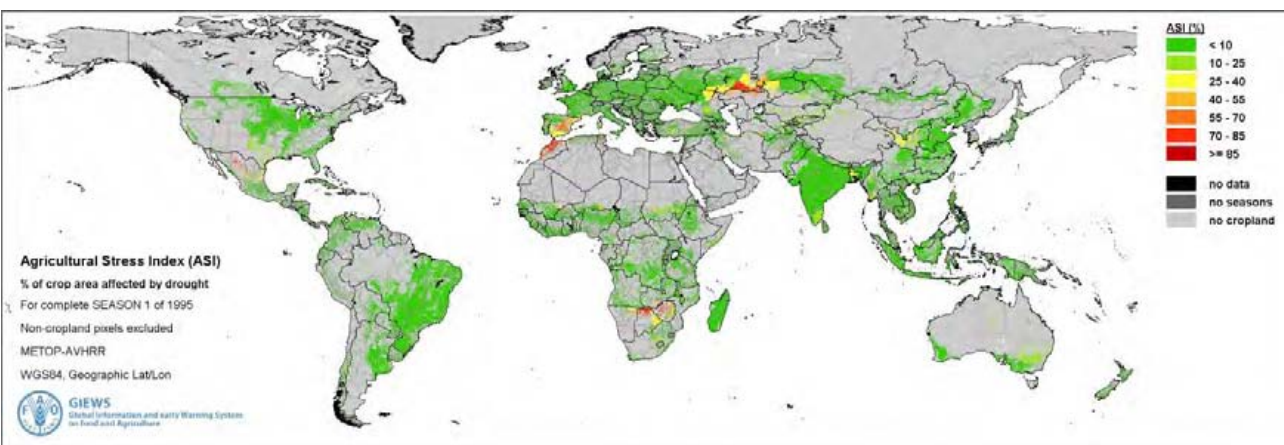
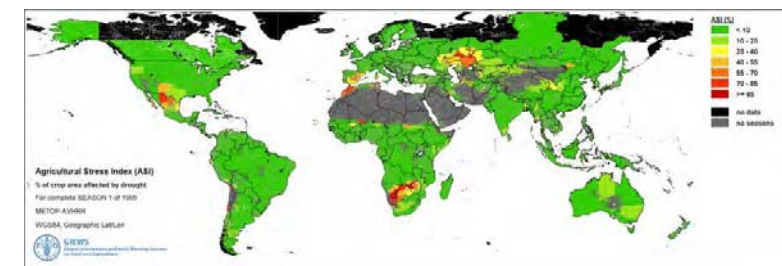
Brasil: In 1993 two million people, with probably another four to six million dependents, were employed on public works because of the lack of agricultural work after sugar cane harvests fell 50% in Pernambuco due to drought. By May 1993 the Marechal Puta dam had lost 54% of its total capacity of nearly 42 millions cubic meters (World Disasters Report: 1994).



1994



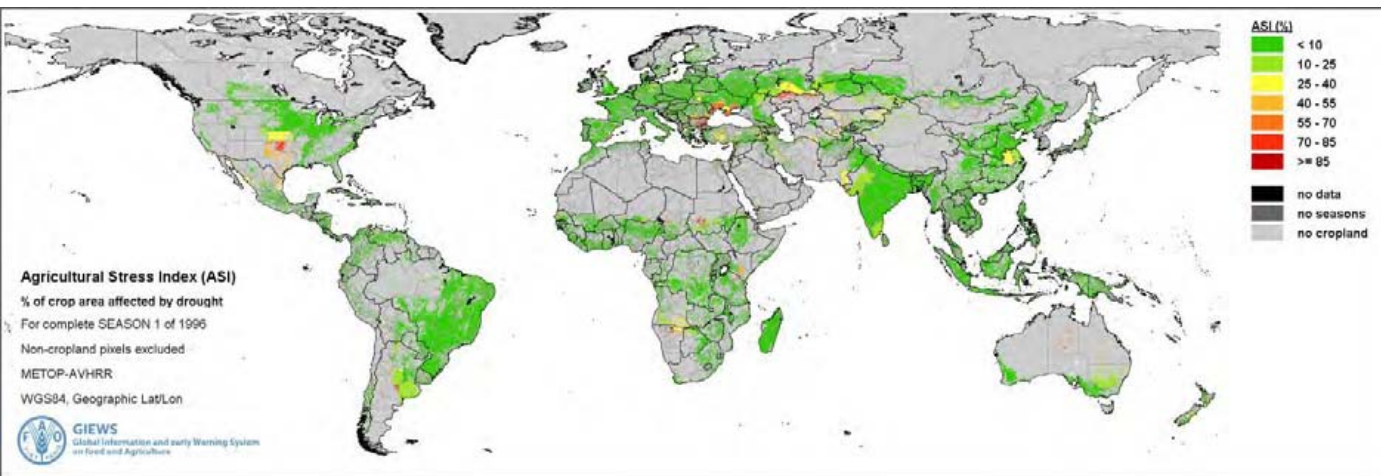
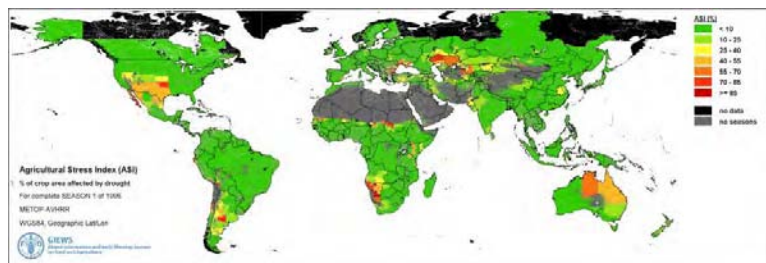
1995



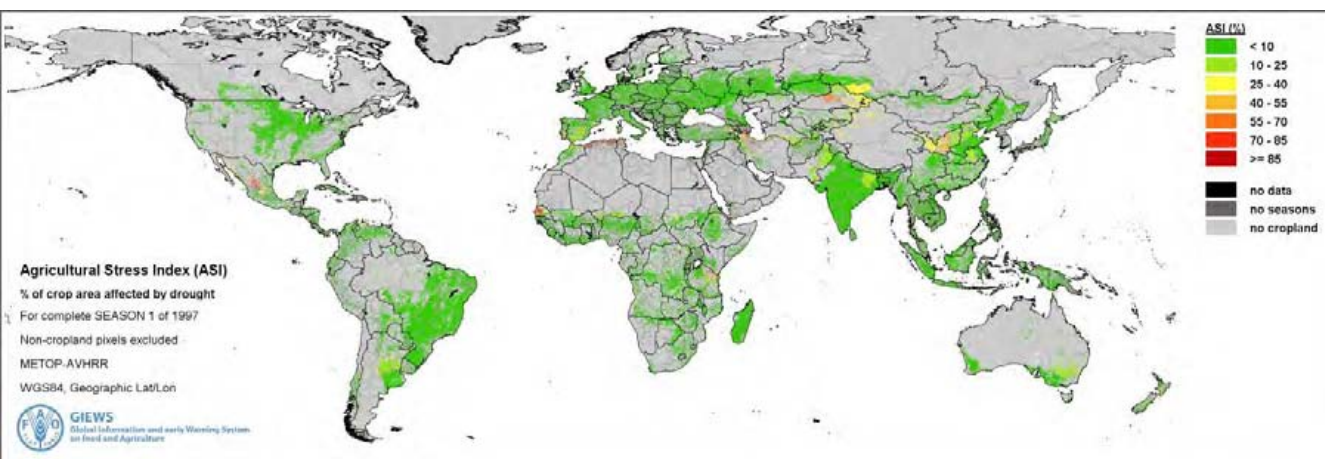
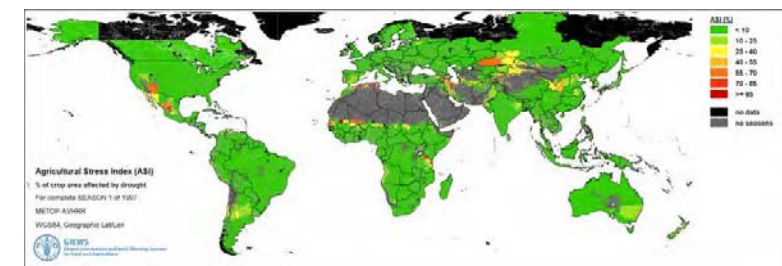
Morocco: Reduced incomes due to *drought* caused GDP to fall by 7.6% in **1995**, by 2.3% in 1997, and by 1.5% in 1999.



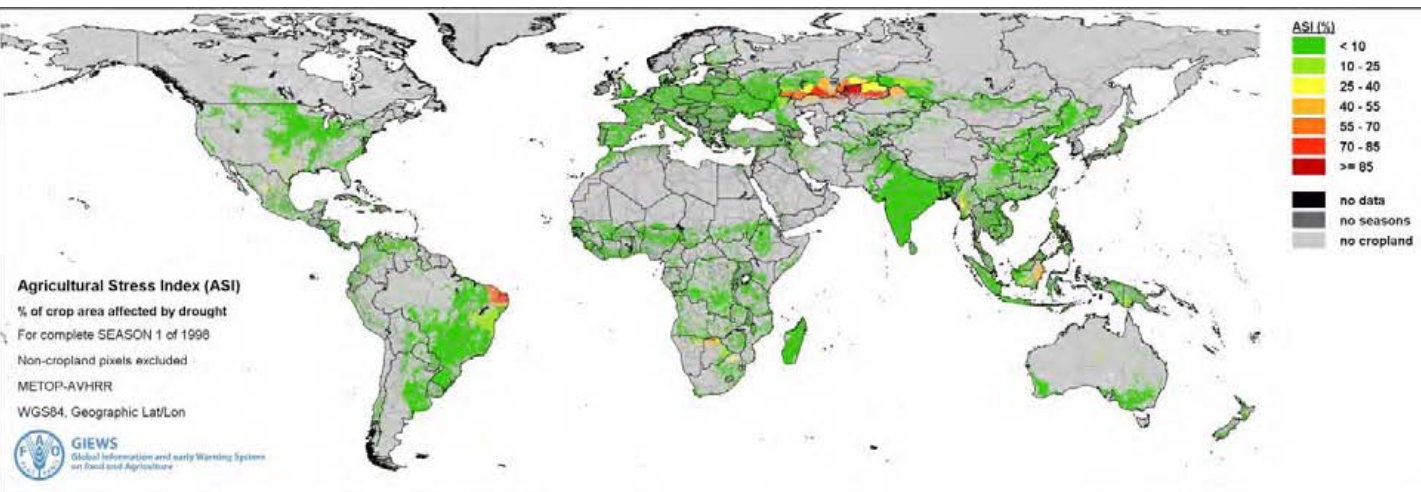
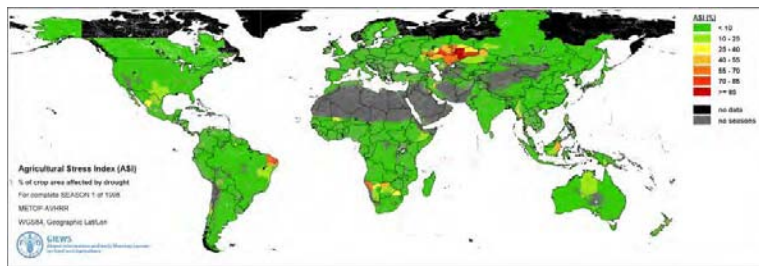
1996



1997



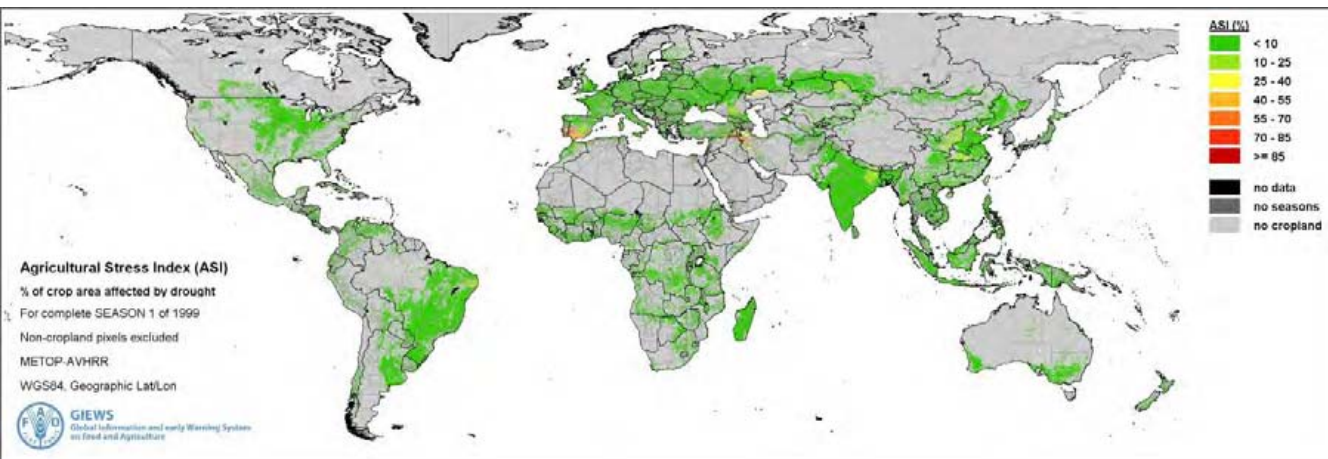
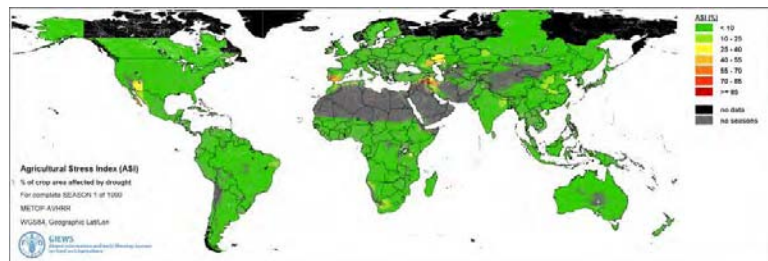
1998



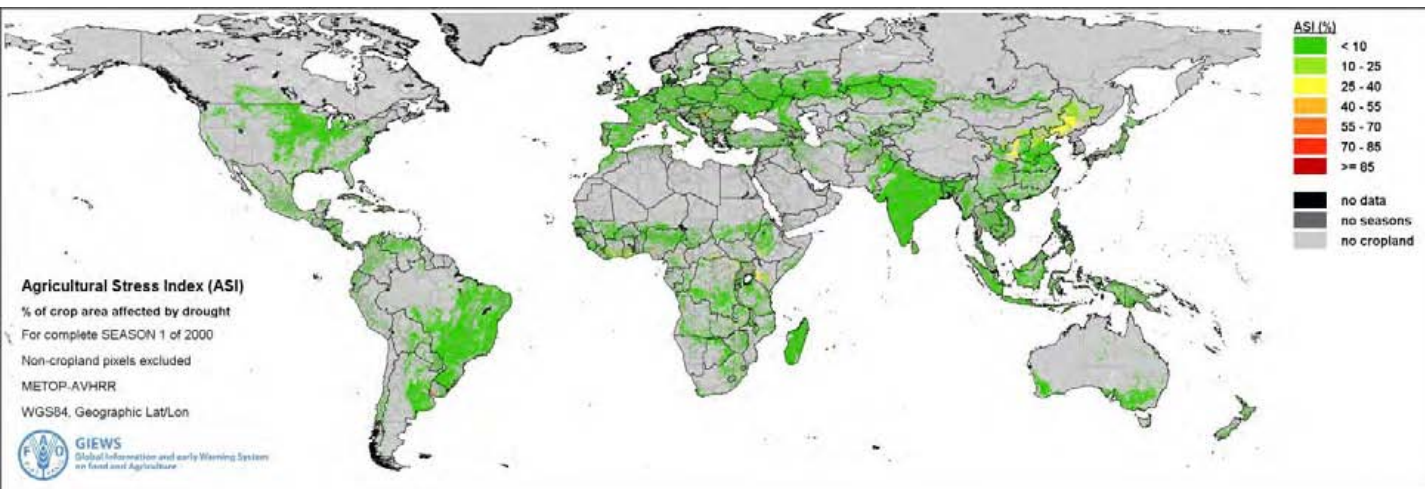
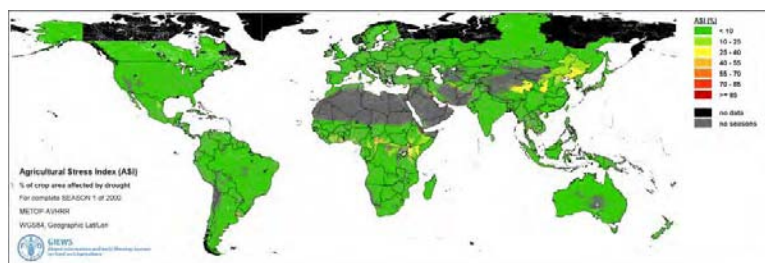
Russia: Severe drought in 1998-1999 led to a harvest of 48 million tons and 60.2 million tons respectively, adding more to the [economic crisis that hit Russia in 1998](#), and thus forcing Russia to accept [humanitarian aid](#) (source Wikipedia) **Brazil:** This season, probably as a consequence of El Niño phenomenon, rainfall has been insufficient or virtually non-existent in large areas of the states of Alagoas, Bahia, Ceará, Pernambuco, Piauí, Sergipe, Paraíba, Rio Grande do Norte, and the northern parts of Minas Gerais and Espírito Santo (GIEWS, 1998)



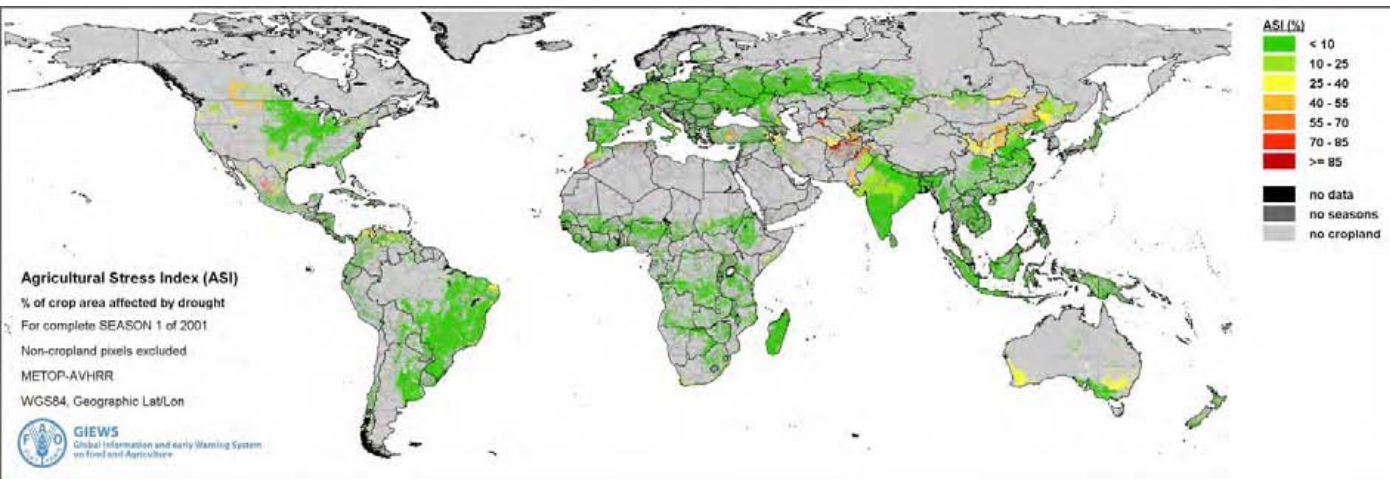
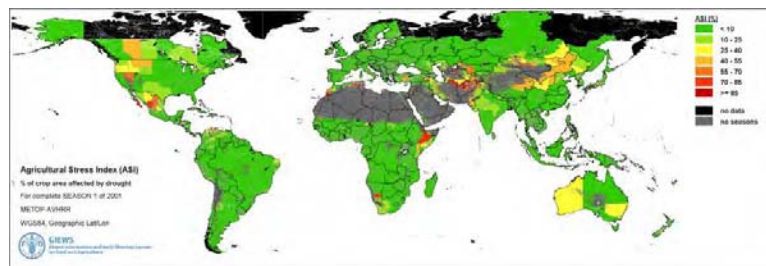
1999



2000



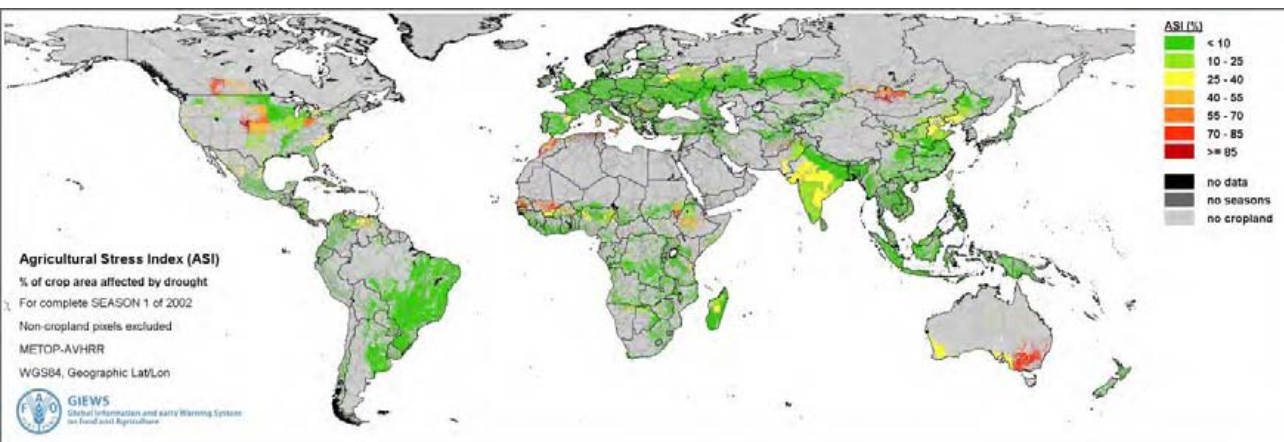
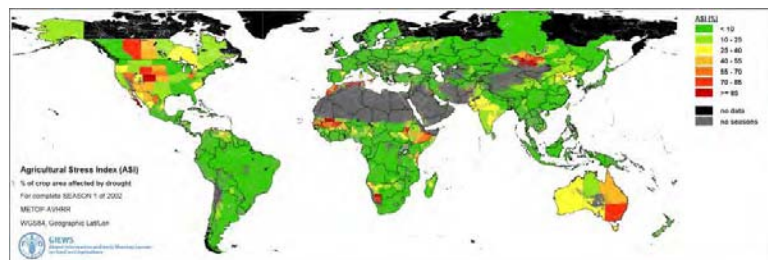
2001



Afghanistan: Rain-fed crops failed in 2001, and irrigated agricultural output was reduced because of a lack of water and failure of infrastructure. Livestock heads were also reduced by 40% from 1998 to 2001.



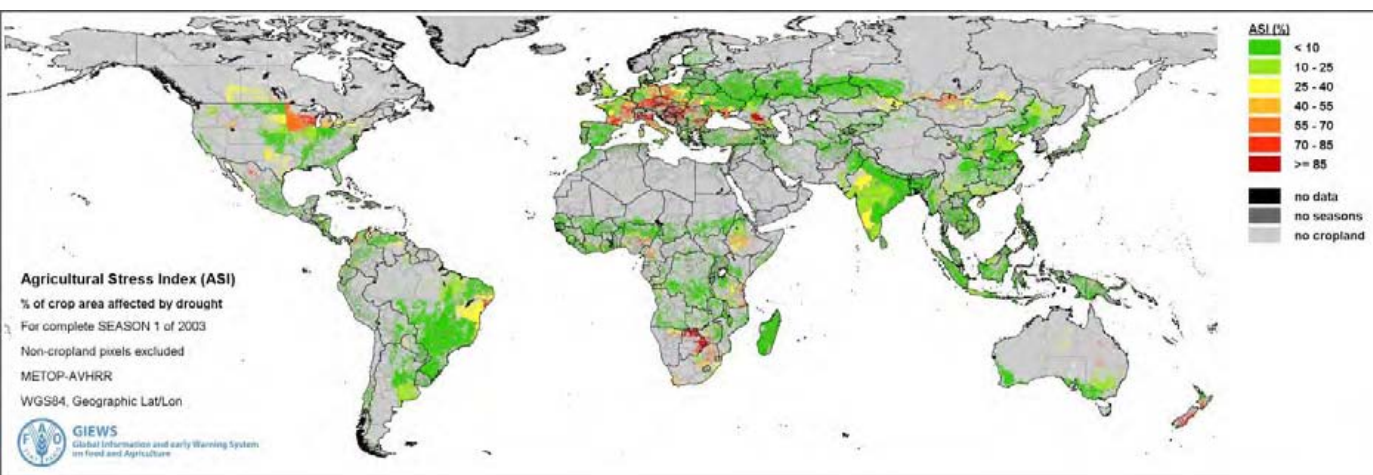
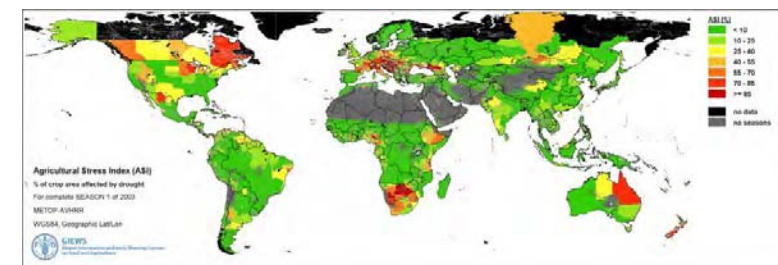
2002



USA: The [Midwest](#) and [Rocky Mountains](#) became victims during 2002; the regions fell victim under exceptional drought which was accompanied by dry conditions, wildfires and hot temperatures over the [Western US](#) and Midwestern State areas. **Australian** annual rainfall data 1900-2004 shows clearly that the 2002 drought was just another cyclic drought.



2003

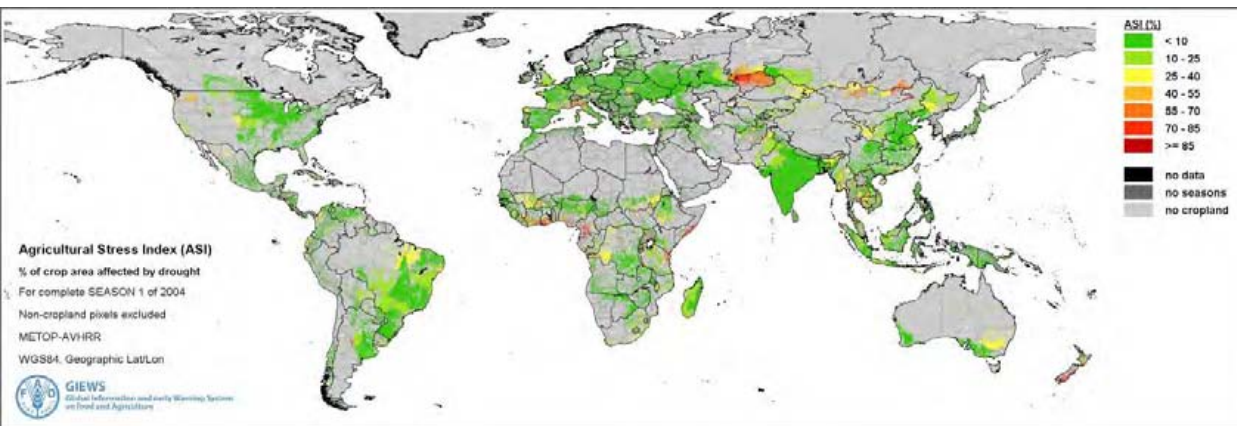
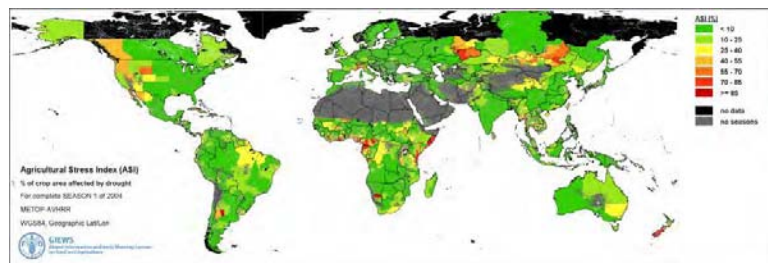


The **2003 European heat wave** was the hottest summer on record in Europe since at least 1540. **France** was hit especially hard. The heat wave led to health crises in several countries and combined with drought to create a [crop](#) shortfall in parts of Southern Europe. Peer reviewed analysis places the European death toll at 70,000.^[2]

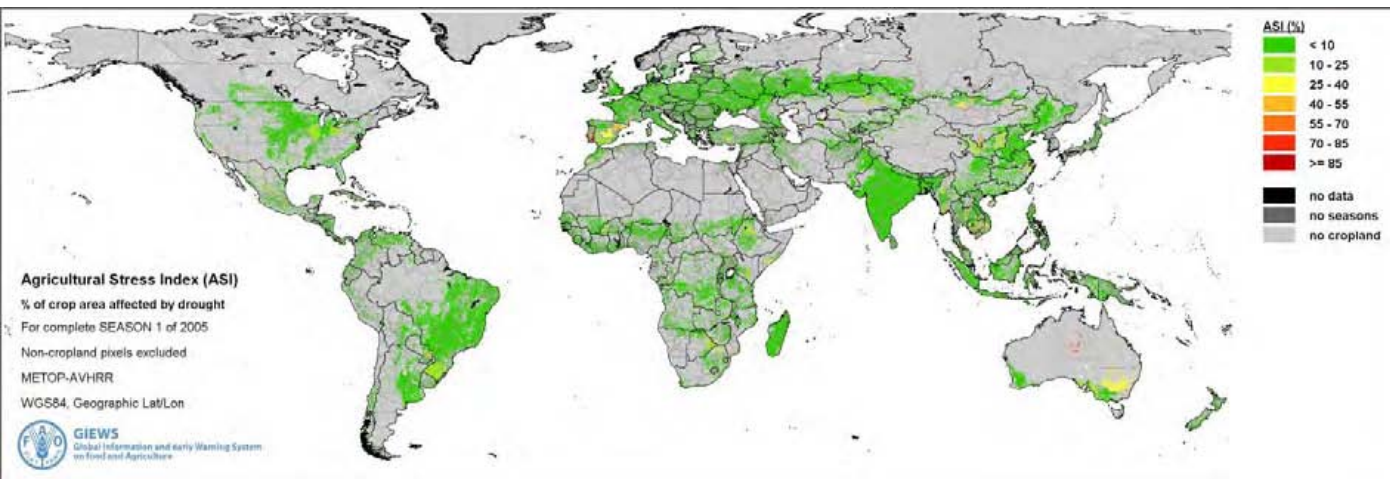
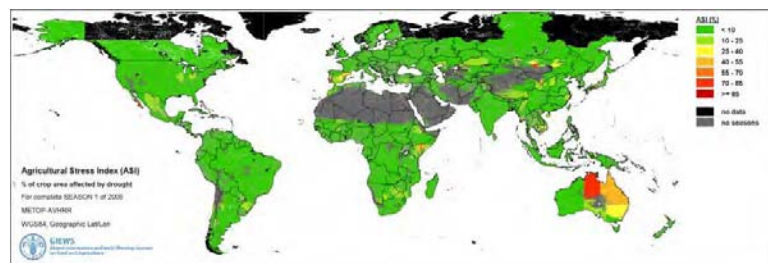
Botswana : The 2003 coarse grain production, mainly sorghum, is forecast to be sharply reduced due to dry weather **South Africa**: In October 2003, the South African government approved an allocation of ZAR 250 million² for drought relief **Mexico**: Sequía en Chihuahua podría suspender suministro para riego en 2003 **New Zealand**: NZ Herald 29.05.2003 A farming slump has wiped more than \$1 billion off New Zealand's gross domestic product. The Ministry of Agriculture and Forestry estimates that agriculture's contribution to GDP fell 15 per cent to \$7.97 billion in the year to March. A cold spring and summer drought - yet to break in parts of the lower North Island



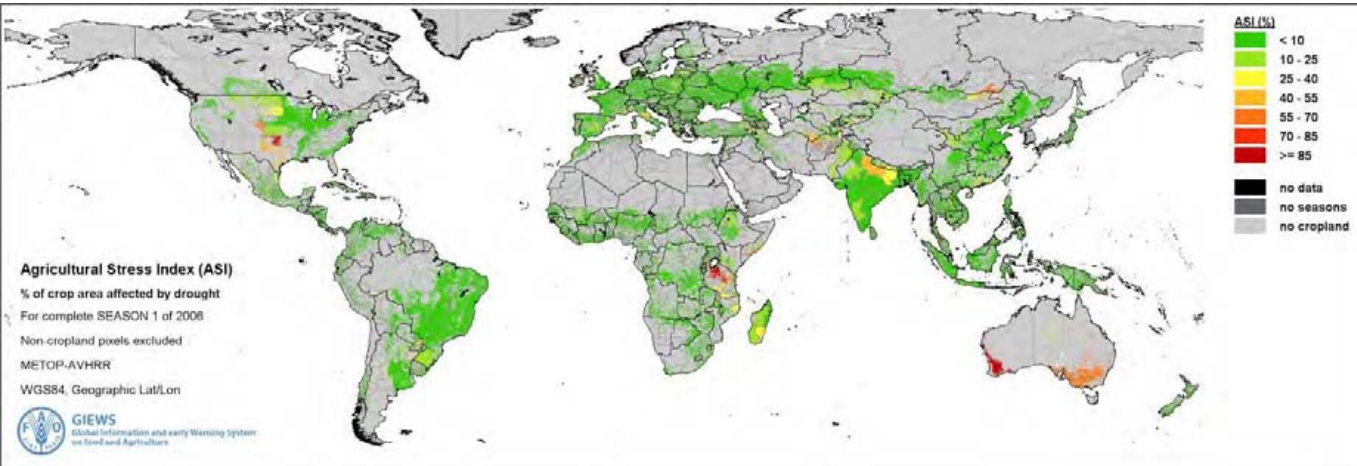
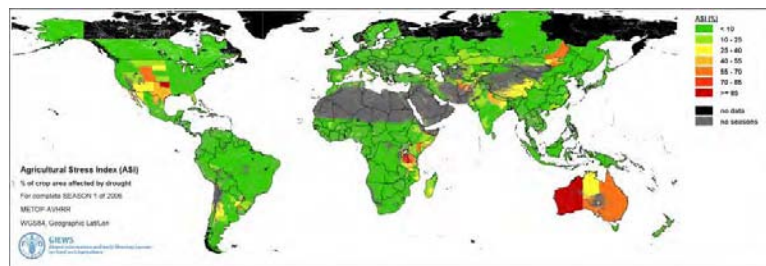
2004



2005



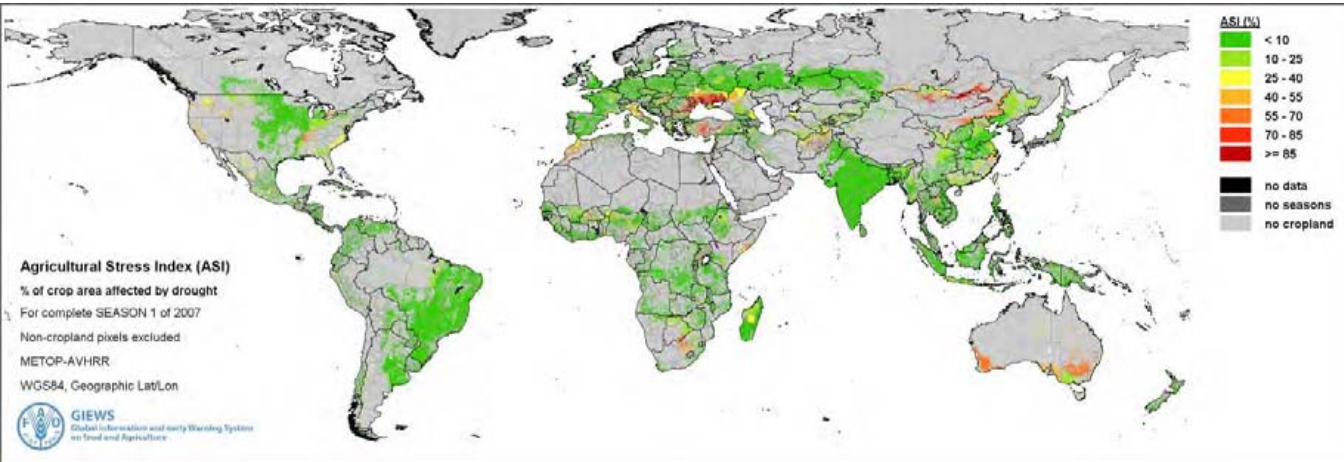
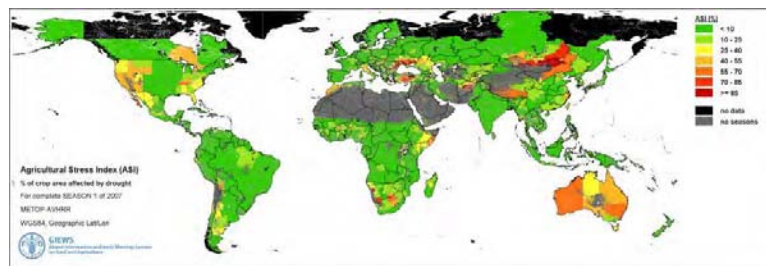
2006



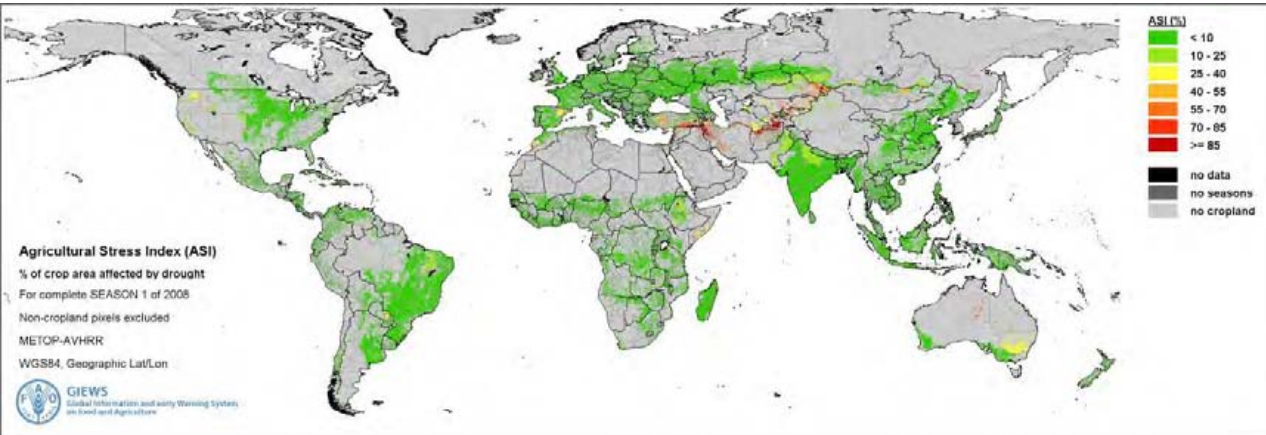
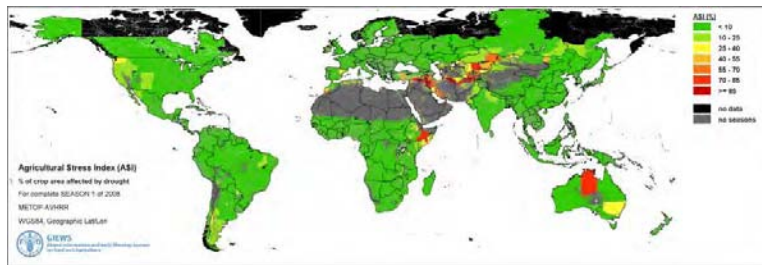
Most **Australian** mainland capital cities are facing a major water crisis with less than 50% of water storages remaining. For example, Melbourne has had rain up to 90% below the average for September and October 2006, compounding the problem of extremely low rainfall from the preceding winter months. **Tanzania:** WFP today urgently appealed for US\$16.6 million to feed 565,000 people in Tanzania facing severe hunger because of drought



2007



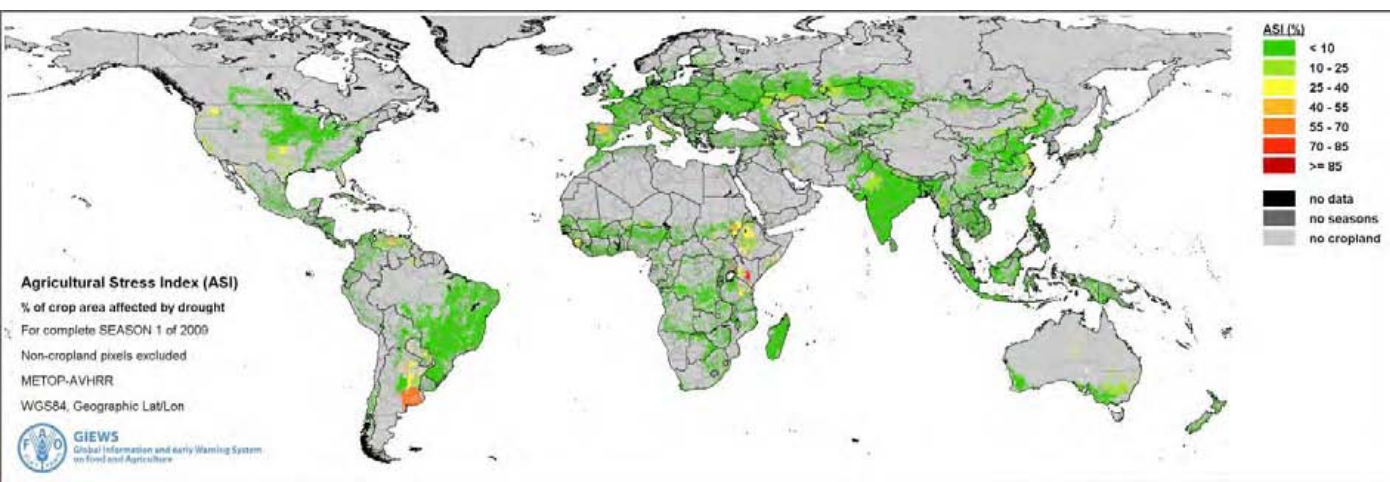
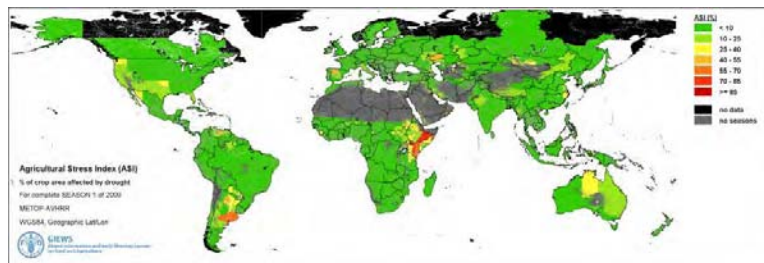
2008



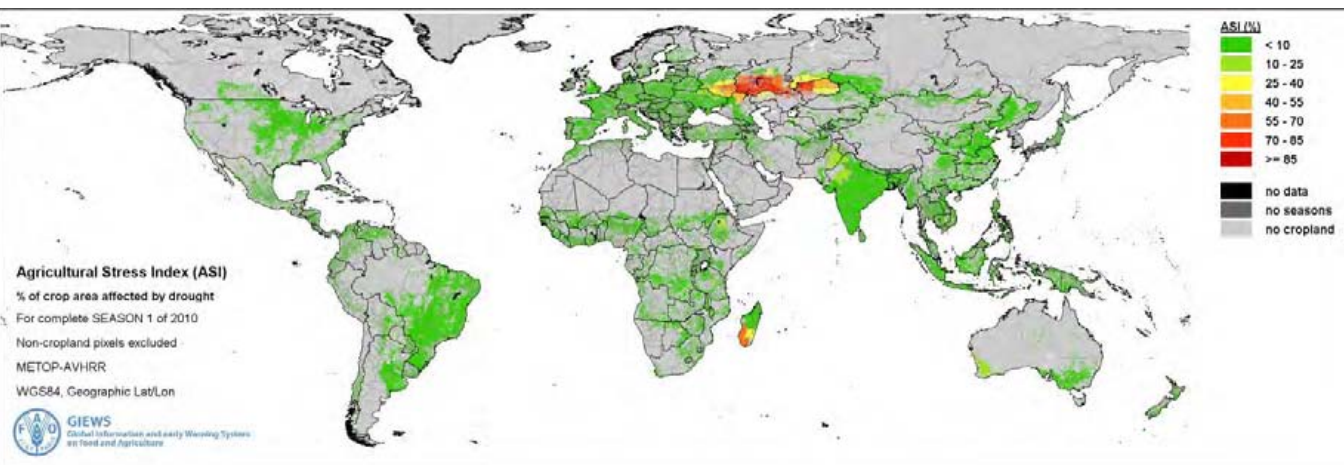
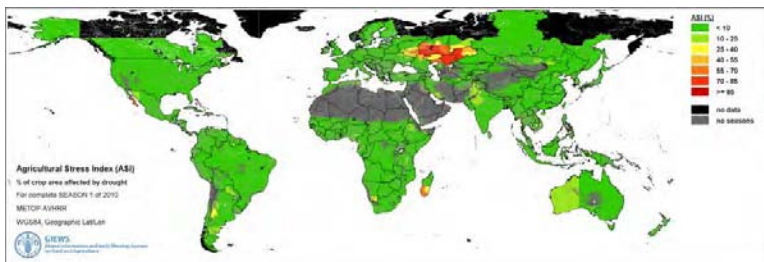
Iran: Approximately 6 million tons of wheat will be purchased from 15 countries in 2009 because of the [drought](#) in **2008**, thus making Iran the largest wheat importer in the world.



2009



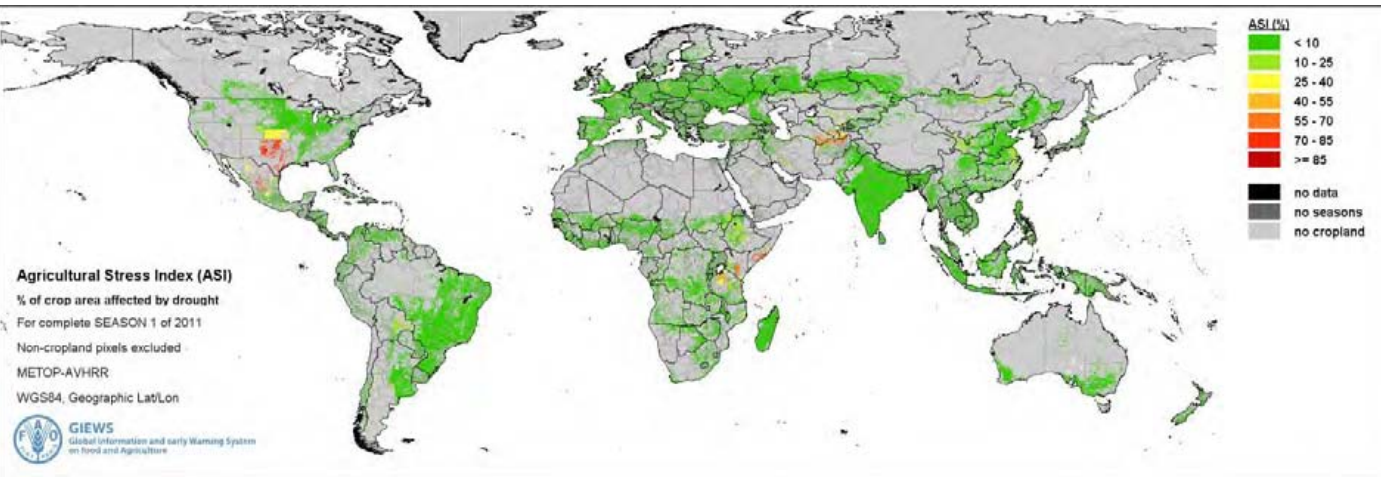
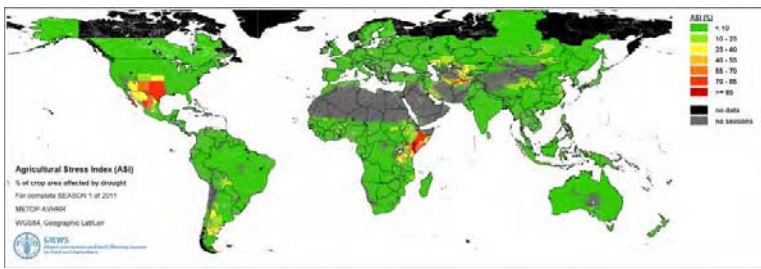
2010



Russia has been gripped in a severe drought from July 2010, which may see grain production fall by 20-25.



2011



Eastern Africa: Since mid-July 2011, a severe [drought](#) has been affecting the entire [East Africa](#) region.^[6] Said to be "the worst in 60 years",^[7] the drought has caused a severe [food crisis](#) under [Somalia](#), [Djibouti](#), [Ethiopia](#) and [Kenya](#) that threatens the livelihood of 9.5 million people. **United States:** Much of Texas is bone dry, with scarcely any moisture to be found in the top layers of soil. Grass is so dry it crunches underfoot in many places. The nation's leading cattle-producing state just endured its driest seven-month span on record, and some ranchers are culling their herds to avoid paying supplemental feed costs. **Mexico:** Mexico is being battered its worst drought in seven decades, which has devastated farm life and is expected to continue into next year. The lack of rainfall has affected almost 70 percent of the country and northern states like Coahuila, San Luis Potosi, Sonora, Tamaulipas and Zacatecas have suffered the most acute water shortage.

