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東華理工大學
EAST CHINA UNIVERSITY OF TECHNOLOGY

Impacts of Climate Change on Rangeland Productivity in Western Asia

Weicheng Wu, PhD, East China University of Technology (ECUT), China
Ayad M. Fadhil, PhD, Salahddin University, Iraq
Claudio Zucca, PhD, ICARDA, Morocco
Ahmad Mhaimeed, PhD, University of Baghdad, Iraq
Waleed Al-Shafie, Ministry of Agriculture, Iraq
Fadi Karam, PhD, Litani Authority, Lebanon

سازمان فضایی ایران
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Outlines

I. Climate change
II. Land Productivity
III. Case Study: Rangeland Productivity in Western Asia (ongoing)
IV. Summary

I: Climate Change

1.1 Concepts and some general abbreviation

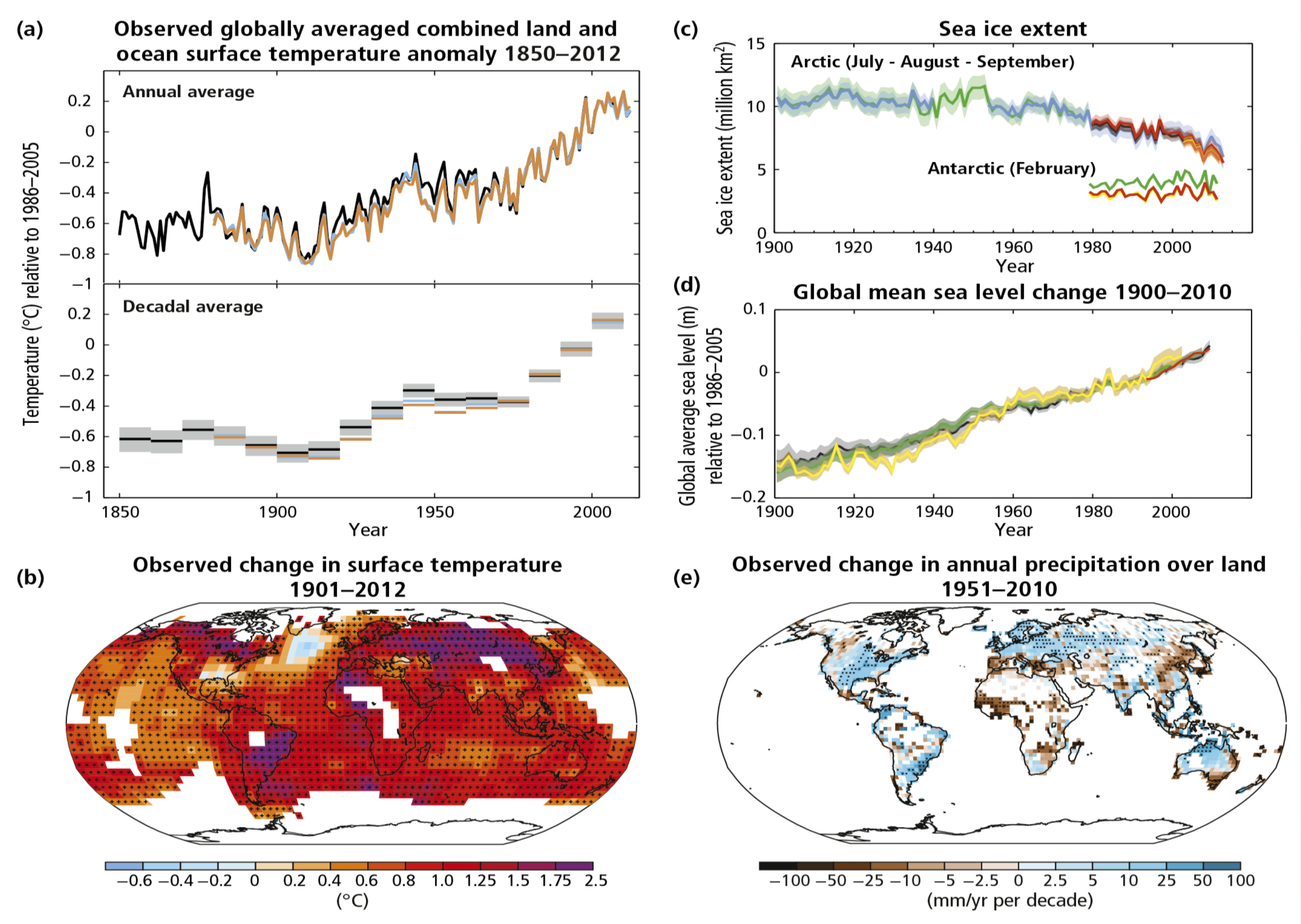
Climate change: A change in climate in certain period, usually, several tens of years or several millions of years, around long-term average conditions, and at local, regional, or global scales.

The **Intergovernmental Panel on Climate Change (IPCC)** set up by WMO and UNEP in **1988,** first incorporated the term "climate change" in its name, inherited from the **Advisory Group on Greenhouse Gases**, created in 1985.

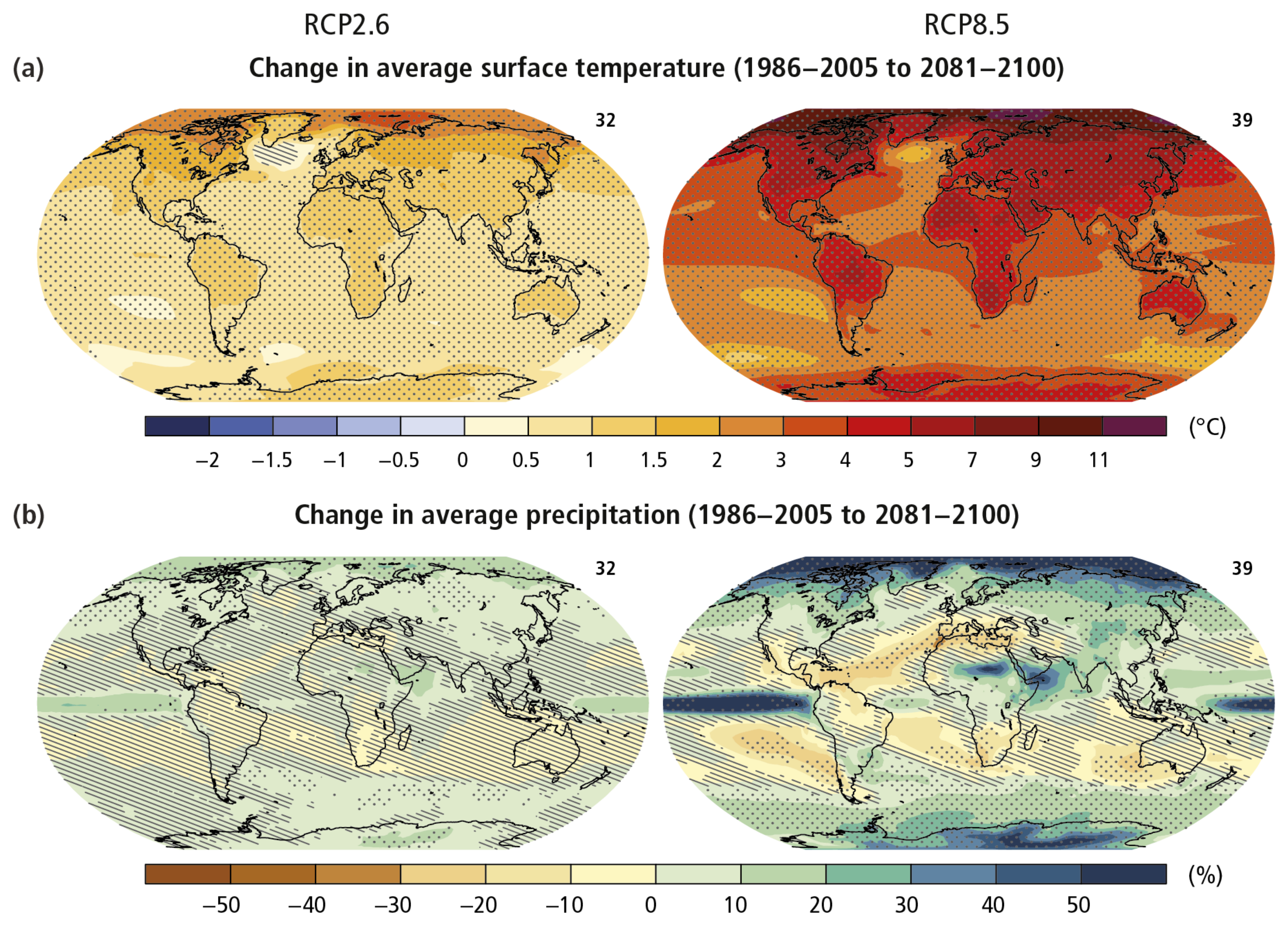
Climate change was **"global warming due to carbon emission".**

Assessment Reports (AR): 1990, 1995, 2001, 2007, 2014

1.2 Observed Change in Climate (IPCC 2014)



1.4 Future Climate Change (IPCC 2014)



IPCC Main Conclusions

- Warming of the climate system is unequivocal (T, Sea Level ↑, Snow and Ice ↓).
- Anthropogenic greenhouse gas emissions (CO_2, CH_4, N_2O) are *extremely likely the dominant cause of* CC.
- Natural and human systems are sensitive to changing climate (mostly negative impacts).
- Future T ↑, Precipitation ↑ but ↓ in dryland ecosystems.

Extreme Events *(very high confidence)*

- Number of cold days and nights ↓
- Number of warm days and nights ↑
- Heat waves ↑ in Asia, Europe, and Australia
- Number of heavy precipitation events (flooding)↑
- Droughts, cyclones and wildfires ↑

(IPCC 2014)

Part II: Land Productivity

2.1 Land productivity (LP)

Capacity or power of land to produce.

- Forest Productivity (ton/ha of C, Biomass or Volume/ha),
- Agricultural Productivity (crop production, ton/ha of Yield),
- Water Productivity (forest & range: ton/ha/mm; croplands: ton/ha/m^3)
- Rangeland Productivity (ton/ha of Biomass, carrying capacity),

Factors: Solar Radiation (SR), CO_2, Air Temperature (T), Rainfall/Water (RF), and Soil Quality (SQ)
Climate Change: T↑, RF ↑ or ↓ , flooding and droughts ↑

2.3 How to Evaluate Productivity ?

LP = f(Solar Radiation, CO_2, T, Rainfall, Soil Quality)

Clearly, CC influences LP !

Normal condition: LP normal
Flooding: LP ↓
Drought: LP ↓
Affected by disease/pest: LP ↓

LP can be evaluated by multiple approaches e.g., by statistics, by remote sensing and field investigation:

2.3.1 Statistical Approaches

Cobb–Douglas Production Function
(Cobb and Douglas, 1928)

$$Y = AK^{\alpha}L^{1-\alpha}$$

Y — Output (Production), K — Capital input, L — Labor input, And α — Output elasticity, and A — Total factor productivity

Mahmood et al (2012) modified the equation for assessing impacts of CC on rice production as:

$$Y = AX_i^{\beta_i} exp^{\varepsilon_i}$$

Y — Production (e.g., wheat or rice production, dependent variable), X_i — *i*th independent variable (all kinds of factors contibuting to production such as soil quality, landform, rainfall and irrigation condition, temperature (max, min, mean), fertilizer usage, labor force investment, etc.), β_i — Coefficient of X_i. A —Production constant, and ε_i — Error term.

$$lnY = \beta_0 + \sum_{i=1}^{n} \beta_i lnX_i + \varepsilon_i$$

β_0 — Constant (=*lnA*)

— A multivariate linear regression model!

Mahmood et al. (2012):

Rainfall ↑ by 5% and 15%, Rice yield ↓ by 5.71% and 15.26%;

Temperature ↑ by 1.5°C and 3.0°C, Rice yield ↑ by 2.09% and 4.33%.

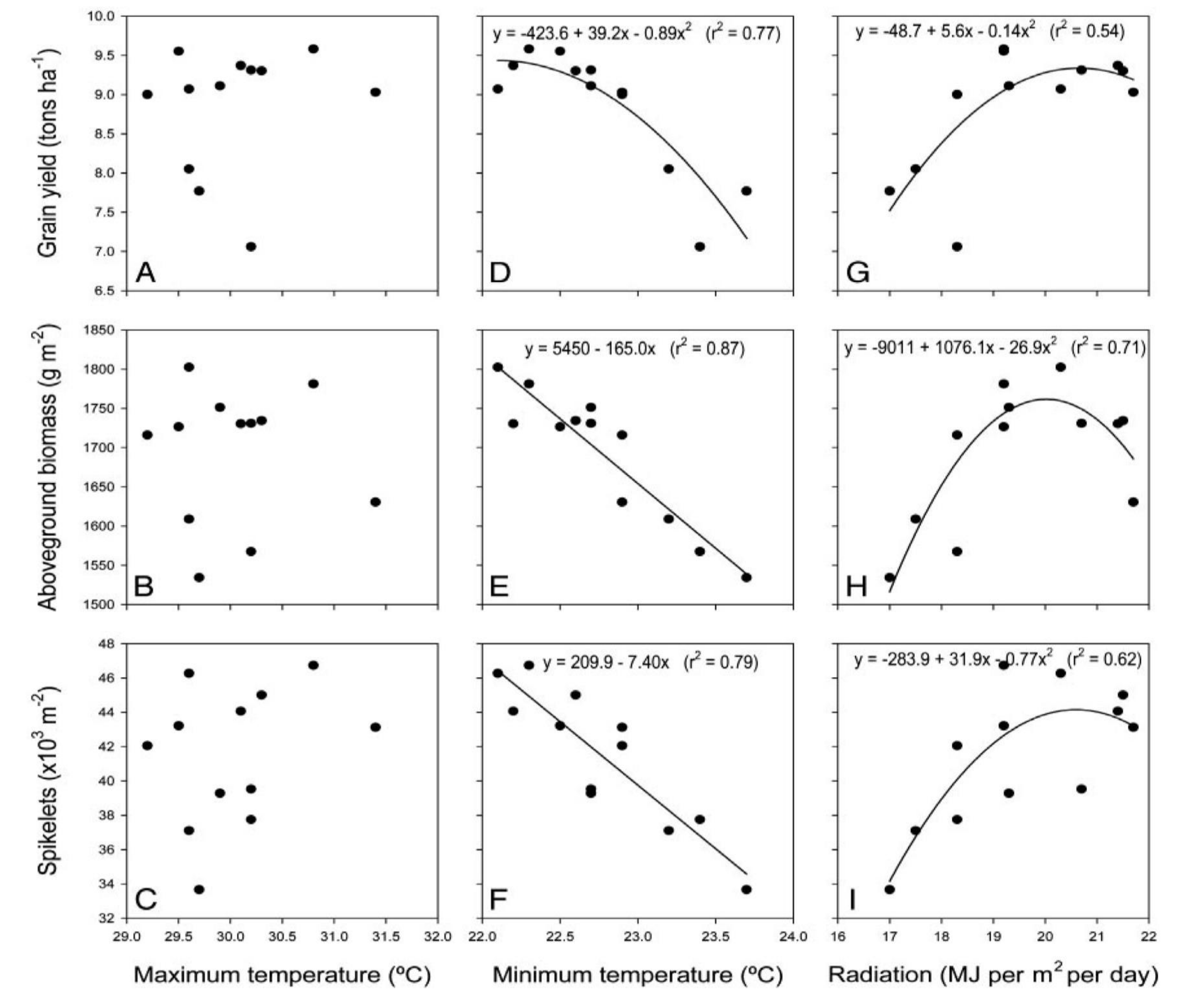
Peng et al. (2004):

Rice yields ↓ while night temperature ↑ associated with global warming.

Wu et al. (2011)

Winter minimum T (the minimum mean T of December-January) ↑, had led to ↓ in wheat production.

Rice yields decline with higher night temperature



(Source: Peng et al. 2004)

2.3.2 Remote Sensing Approaches

Advantages:

- Macroscopic, multiresolution data, capable for multiscale studies from local, to regional/continental, and global
- Periodic and repetitive: 1-26 days, multitemporal and time-series
- Cost-effective:

Rationale:

- Photosynthetic activity, biomass production, crop yields and surface features such as soil moisture, temperature and rainfall can be reflected by remote sensing indicators.

Data required:

- **Weather data**: min, max, and mean daily, monthly, annual temperature; daily, monthly and annual rainfall; daily, monthly and annual evaporation; wind direction and speed; humidity; solar radiation, etc., if possible.
- **Remote sensing data:** Time-series NDVI, T, PET

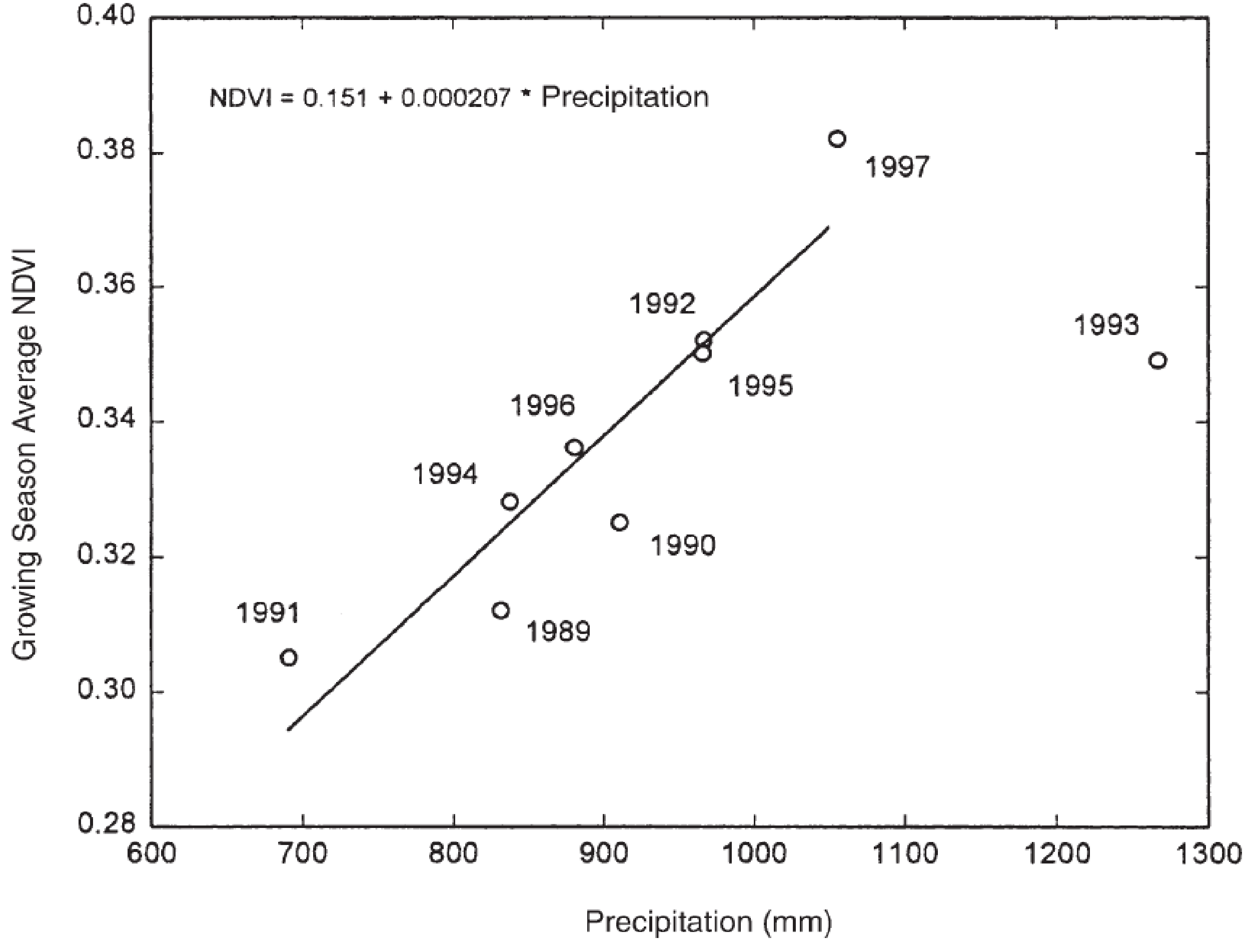


Figure 4. Average growing season NDVI as a function of precipitation received during the current growing season plus the seven preceding months (15-month total precipitation). The linear regression line was calculated using values for all years except 1993, which was an exceptionally wet year.

(Source: Wang et al. 2003)

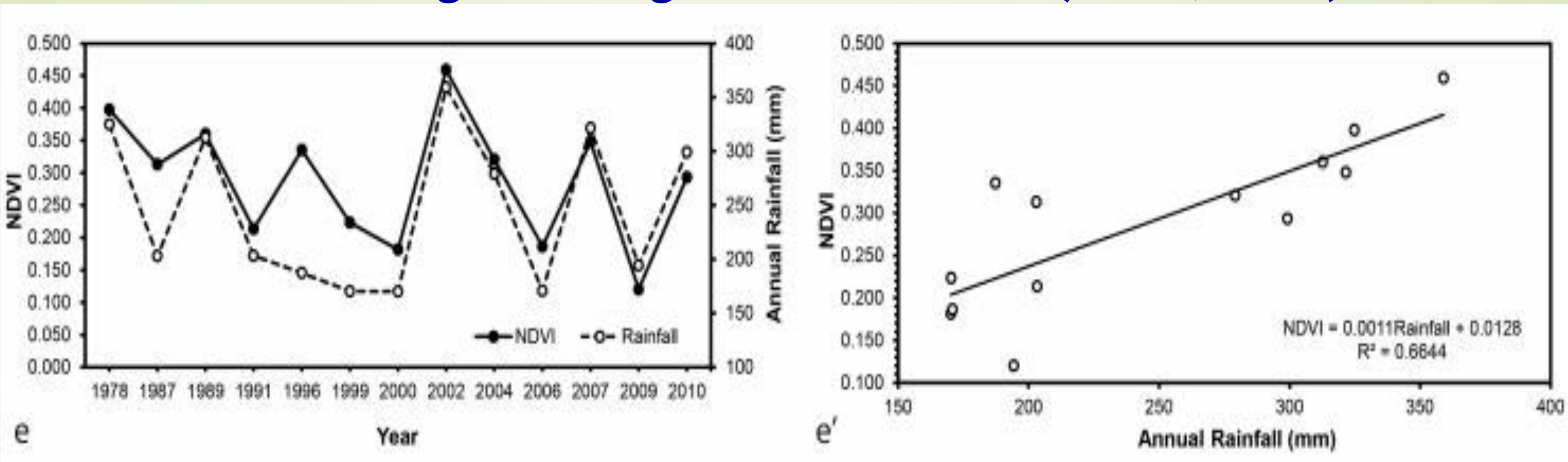
Rainfall-related shrub biomass production in Drylands

Biomass Models	Error	Multi R^2
TFB ($Mg\ ha^{-1}$) = -210.036+0.164CC+2.178RF	± 1.005	0.969
TFB ($Mg\ ha^{-1}$) = -360.992+3.758RF	± 1.155	0.955
TDB ($Mg\ ha^{-1}$) = -193.599+2.019RF	± 0.847	0.919
CC (%) = -740.312+93.937NDVI+7.642RF	± 3.342	0.949

TFB = Total fresh biomass production
TDB = Total dry biomass production
CC = Canopy cover; RF = 4 months' rainfall before image acquisition

(Zucca, Wu et al 2015)

Peak NDVI of non-grazed rangeland vs annual RF (Ordos, China)



(Wu et al. 2013a)

Rangeland biomass: B_H = 0.00216*(100*NDVI)$^{1.7}$ (ton/ha)

(Devineau et al 1986; Zucca, Wu et al 2015)

Rangeland biomass: B_H = 16.31exp(4.26NDVI) (ton/ha)

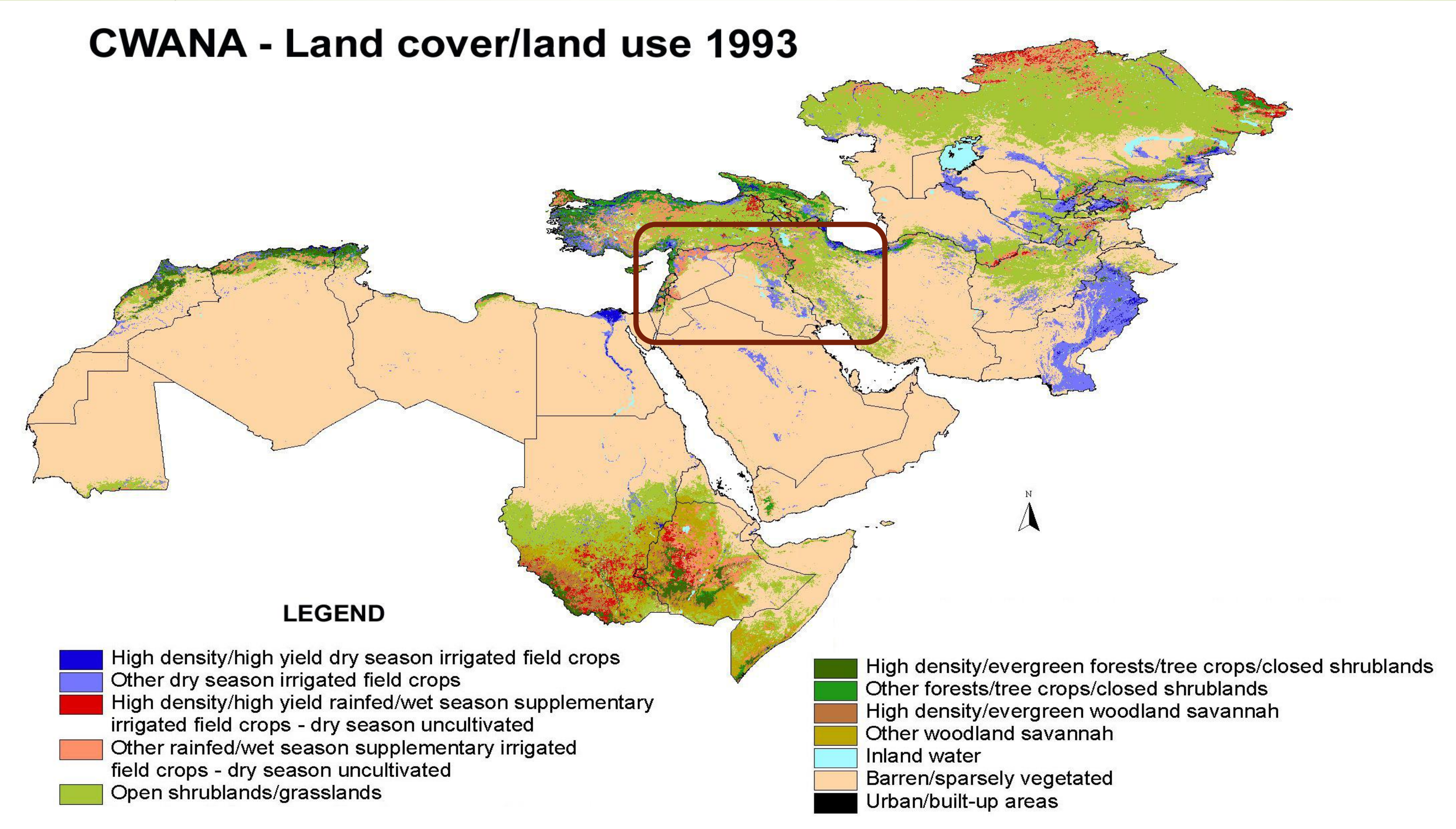
(Kawamura et al. (2005); Wu and De Pauw 2010)

Shrub rangeland biomass: B = -2.923+21.486*NDVI (ton/ha) or

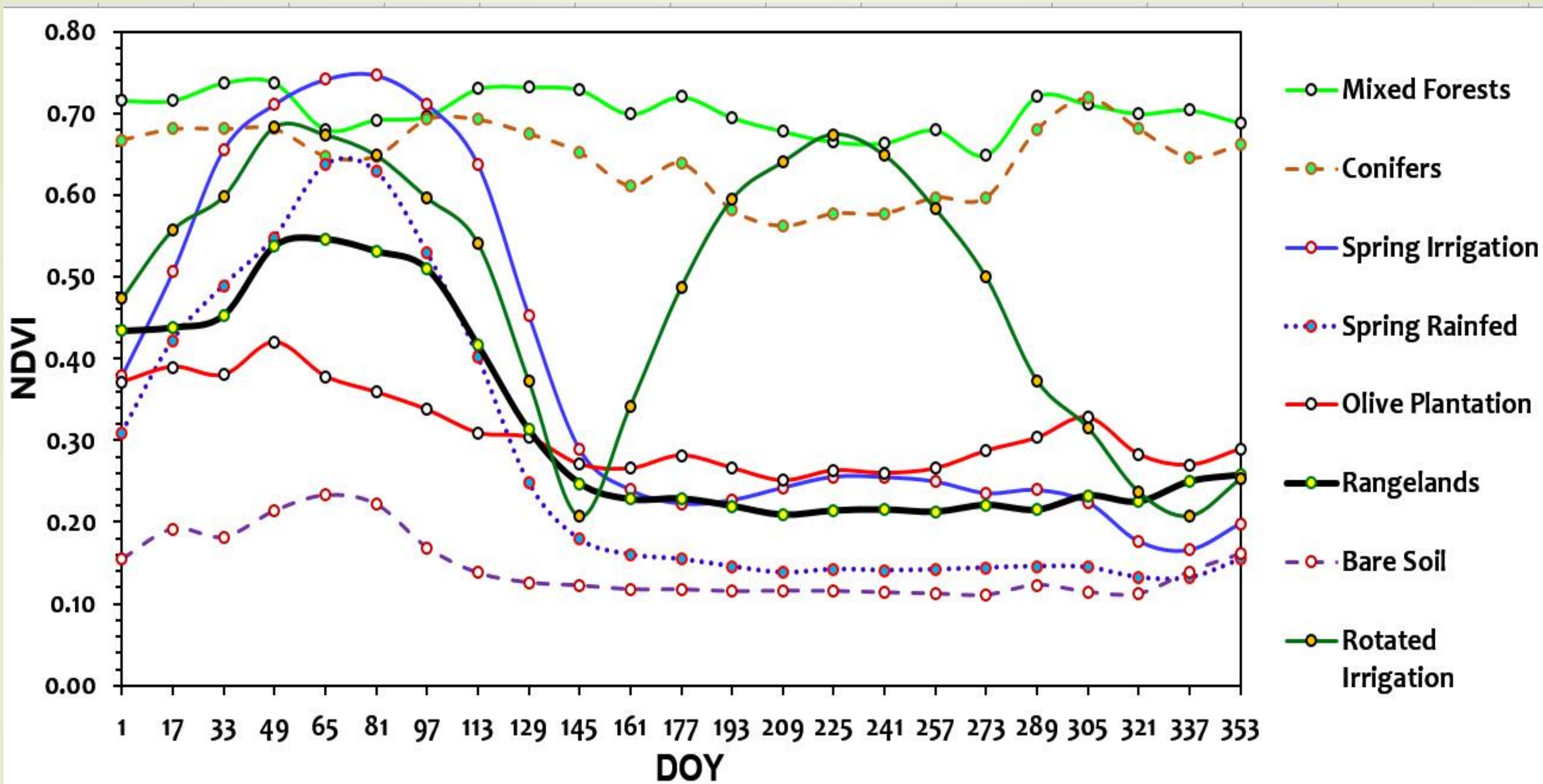
B= 10.563*NDVI-0.442 (ton/ha)

(Pereira et al. 1995; or Al Bakri and Taylor 2003)

Part III: Case Study: Rangeland Productivity in Western Asia



(Celis et al. 2007)



NDVI Trajectories of different land use and cover types derived from MODIS NDVI of 2010, taking Northwestern Syria as an example

Data used:

(1) SPOT Vegetation NDVI, MODIS NDVI
(2) ESA GlobalCover Land Use Map (300m)
(3) Monthly rainfall data
(5) Models: Forementioned remote sensing biomass models

Procedure:

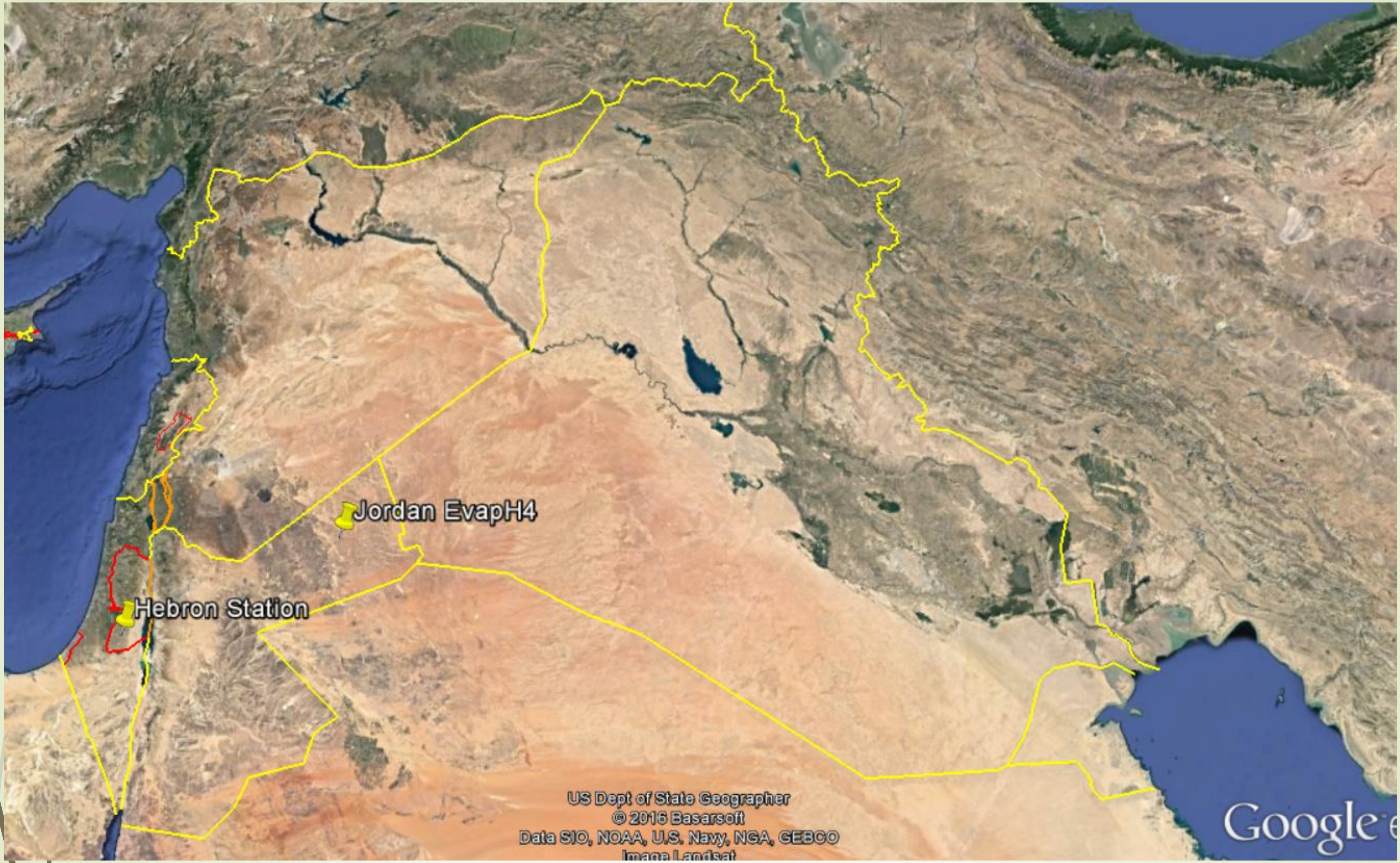
(1) Derivation of the annual maximum/peak NDVI from the time-series SPOT VGT data
(2) Analysis of SPI (McKee et al 1993) and SPEI (Vicente-Serrano et al. 2010) based on the weather station data to identify the drought years [Note: in terms of their development theory, SPEI seems better for drought analysis, but a number of weather stations in the region have no T measurement]
(3) Development of masks of the rangelands and grasslands from the GlobalCover

Procedure (Cont.):

4) Selection of the relevant Max NDVI based biomass production models
5) Application of the selected models to the Max NDVI for estimating biomass production
6) Mosaicking the biomass maps of different rangelands
7) Compare the production between drought years and normal years
8) In case of climate change as projected by IPCC, what will be the rangeland biomass production?

LC	Value	Label
1	11	Post-flooding or irrigated croplands (or aquatic)
2	14	Rainfed croplands
3	20	Mosaic cropland (50-70%) / vegetation (20-50%)
4	30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)
5	40	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)
6	50	Closed (>40%) broadleaved deciduous forest (>5m)
7	60	Open (15-40%) broadleaved deciduous forest/woodland (>5m)
8	70	Closed (>40%) needleleaved evergreen forest (>5m)
9	90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)
10	100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)
11	110	Mosaic forest or shrubland (50-70%) / grassland (20-50%) **Note: Grassland 35%**
12	120	Mosaic grassland (50-70%) / forest or shrubland (20-50%) **Note: Grassland 60%**
13	130	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)
14	140	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)
15	150	Sparse (<15%) vegetation
16	160	Closed to open (>15%) broadleaved forest regularly flooded - Fresh or brackish water
17	170	Closed (>40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water
18	180	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water
19	190	Artificial surfaces and associated areas (Urban areas >50%)
20	200	Bare areas
21	210	Water bodies
22	220	Permanent snow and ice
23	230	No data (burnt areas, clouds,…)

In the study area, there are no classess of 5, 9, 12, 15, 16 and 17


Jordan EvapH4
Hebron Station
US Dept of State Geographer
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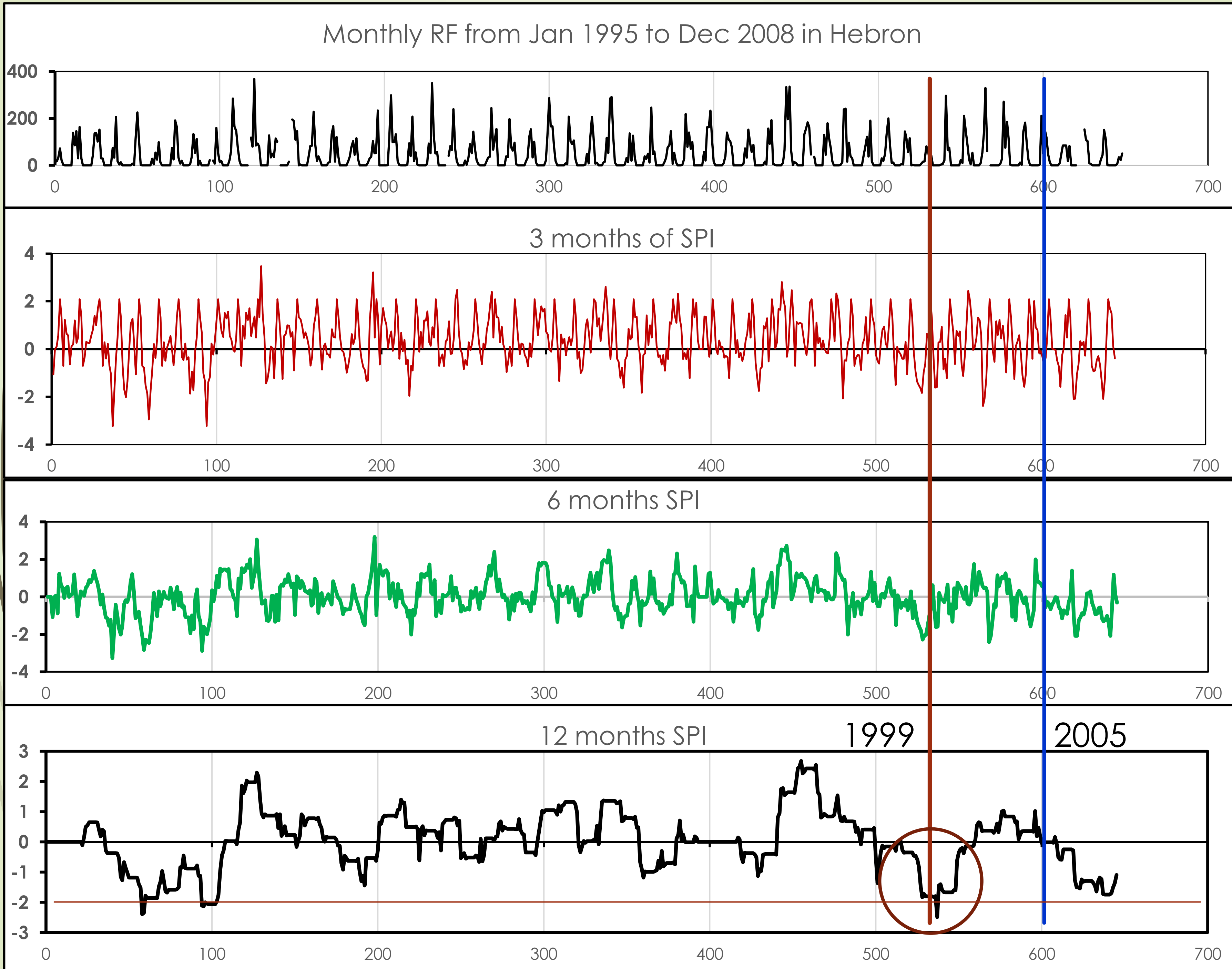
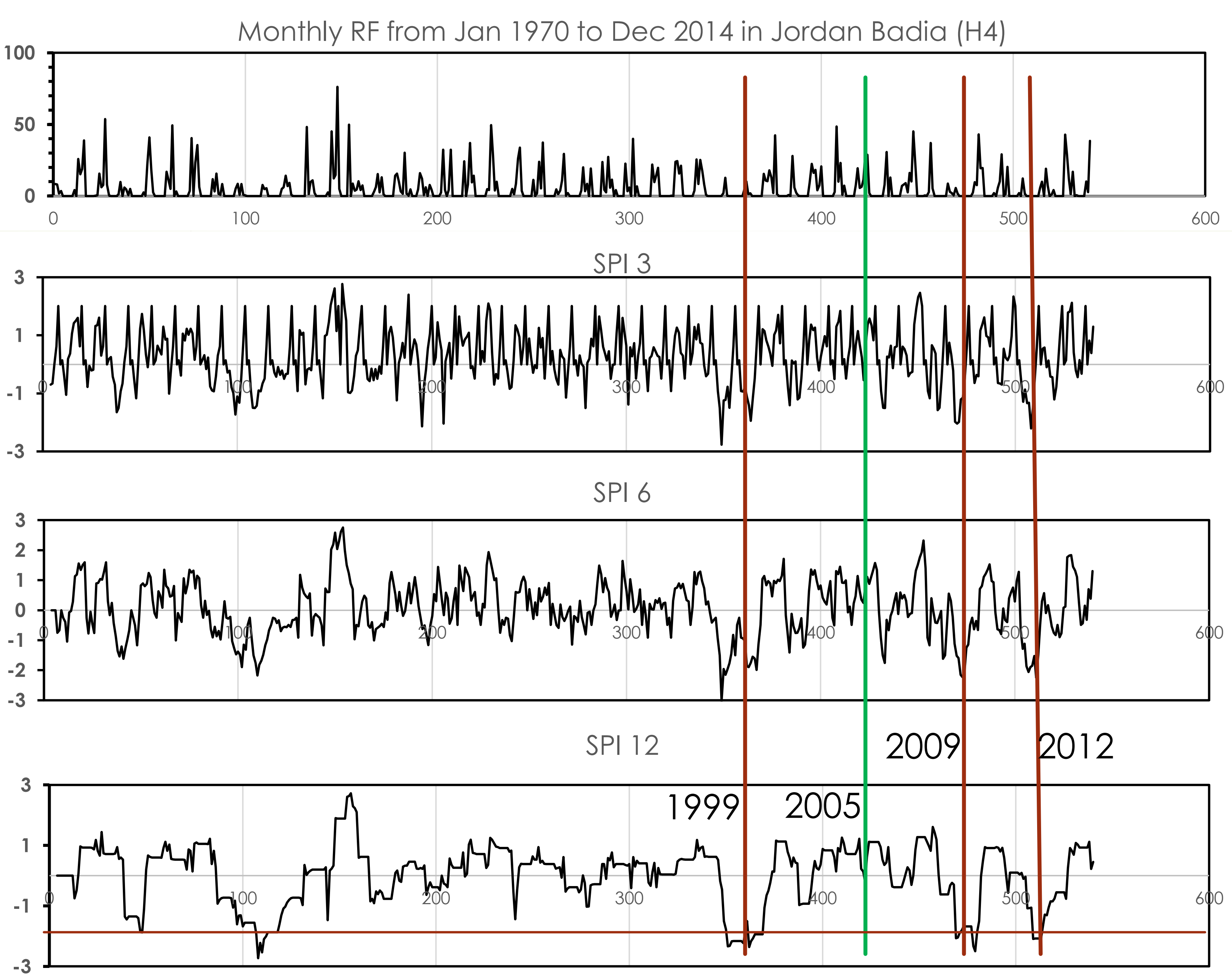
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google



Monthly RF from Jan 1995 to Dec 2008 in Hebron
3 months of SPI
6 months SPI
12 months SPI
1999
2005



Monthly RF from Jan 1970 to Dec 2014 in Jordan Badia (H4)
SPI 3
SPI 6
SPI 12
1999
2005
2009
2012

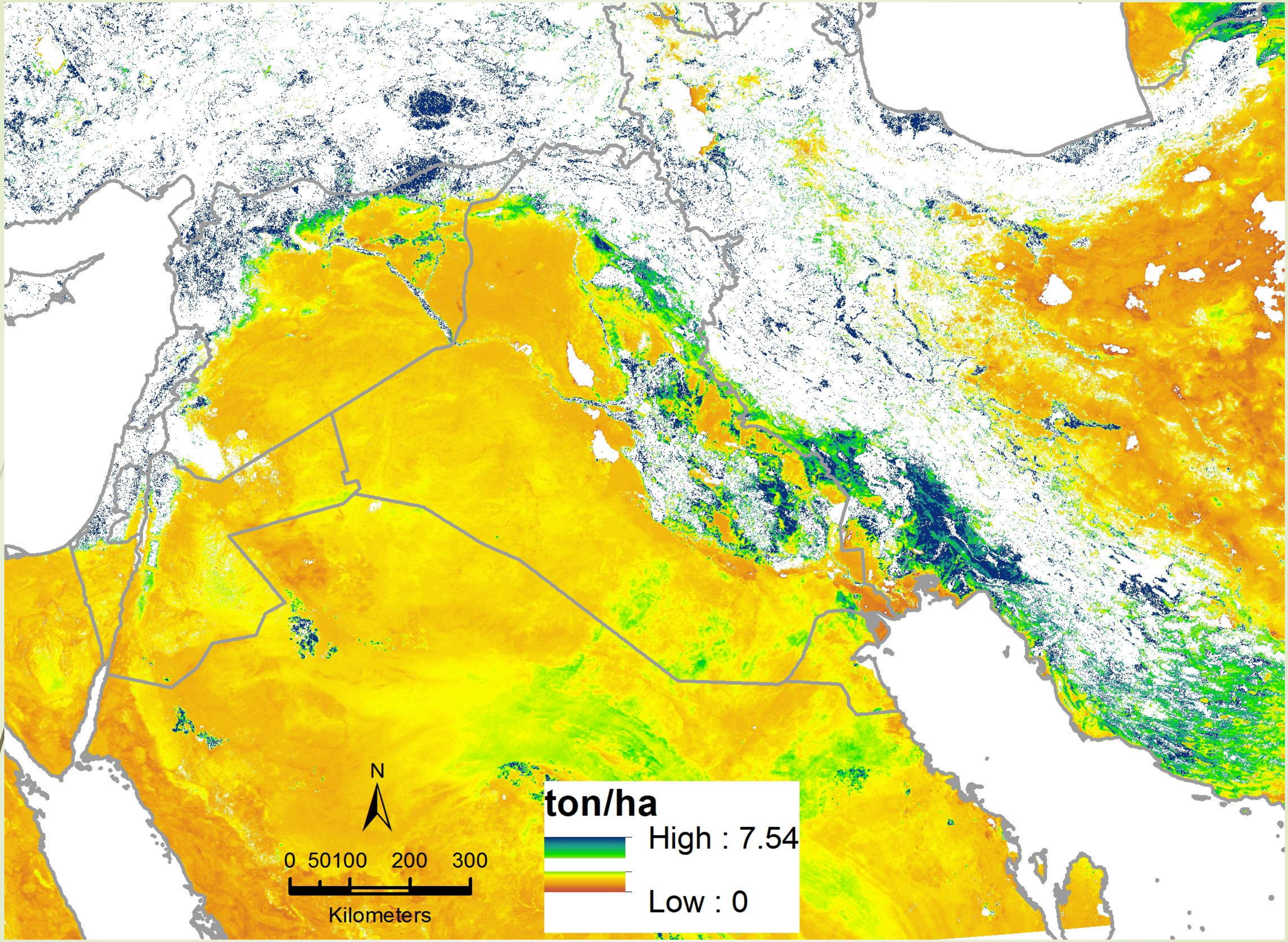
Some Results

1) Recent drought years: 1999, 2009, 2012

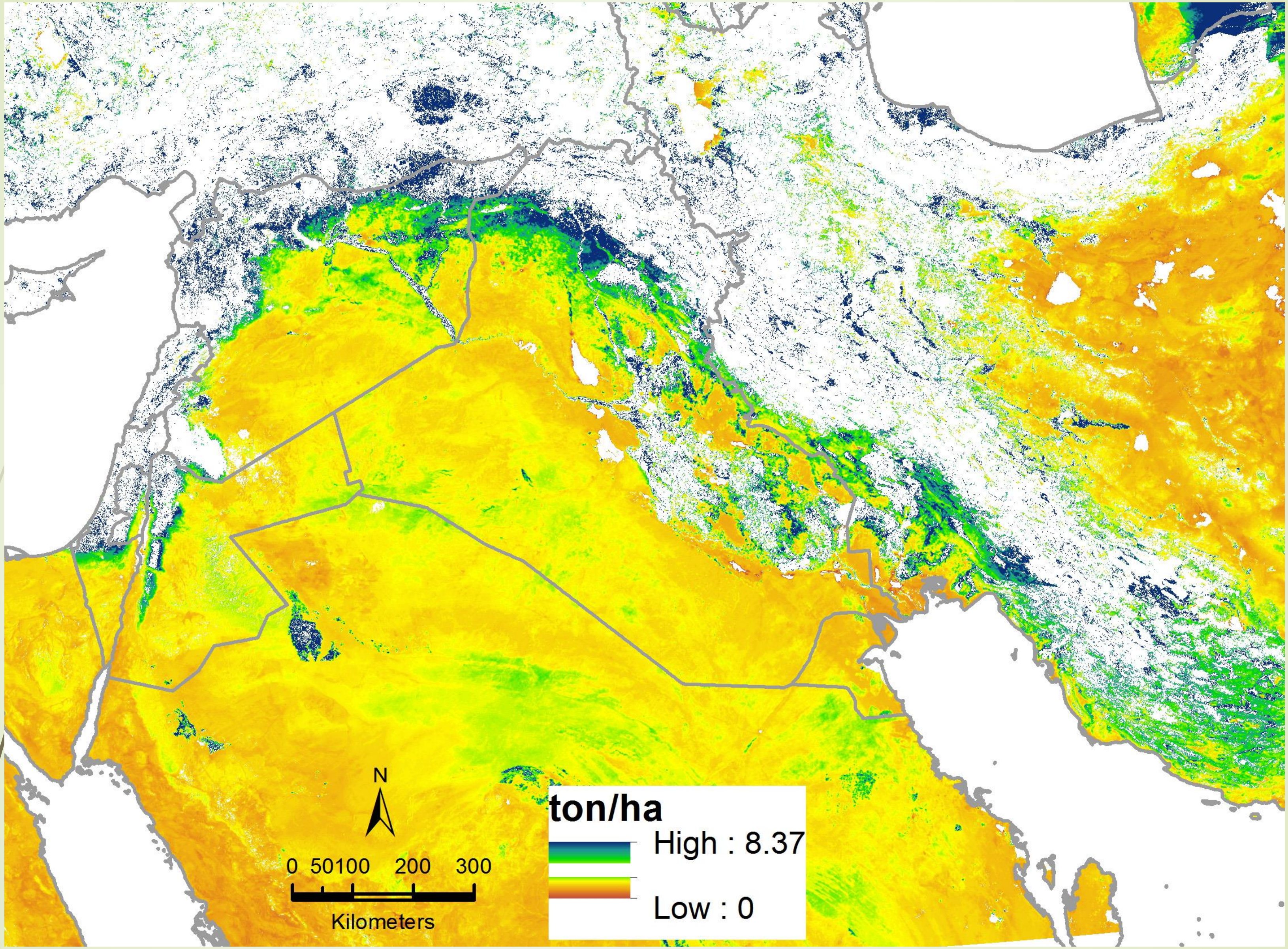
2) Rangeland Production in Western Countries (ton)

Country Name	1999	2005
Bahrain	101	104
Gaza Strip	1561	2229
Iraq	152517	197542
Israel	6992	10013
Jordan	29041	40155
Kuwait	6127	6377
Lebanon	2938	3015
Syria	73337	105978

Rangeland Production in Western Asia in 1999(drought year)



Rangeland Production in Western Asia in 2005



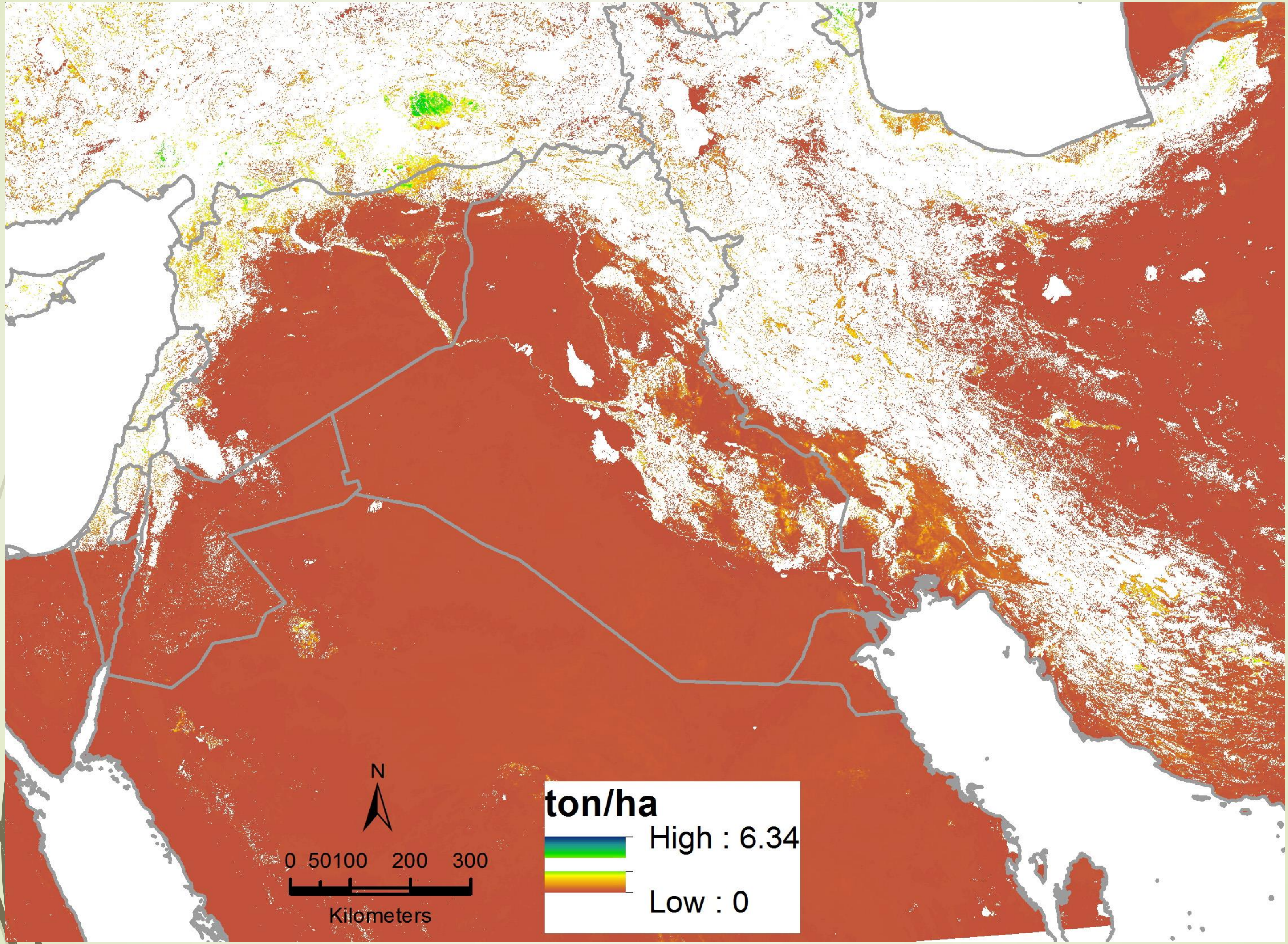
If considering the impacts of change in T, rainfall on NDVI to project future productivity.

IPCC(2014): 2080-2100: Annual RF↓ **10-20%** (about 30-60mm) in ME; T↑ **1.5-7°C,** Evaporation ↑; Water resources ↓

Then NDVI of rangeland ↓ by 0.045-0.079

Rangeland biomass production reduced by 28-72kg/ha

Possible Rangeland Production in 2081 in Western Asia



In a case of climate change+drought

Part IV. SUMMARY

1. Climate changes (CC) are complex phenomena and may have different expressions in different times and spaces, requiring a holistic analysis for a specific region or area using multisource data.

2. Though simple, this study provides a direct way to assess the impacts of CC on rangeland productivity and gives us an overview of our future.

3. No matter whether CC projection is reliable or not, human has to get ready for mitigating such potential impacts of CC if it really happens.

Thank you for your attention!

Contact of Weicheng WU: wuwc123@gmail.com / wchwu@ecit.cn