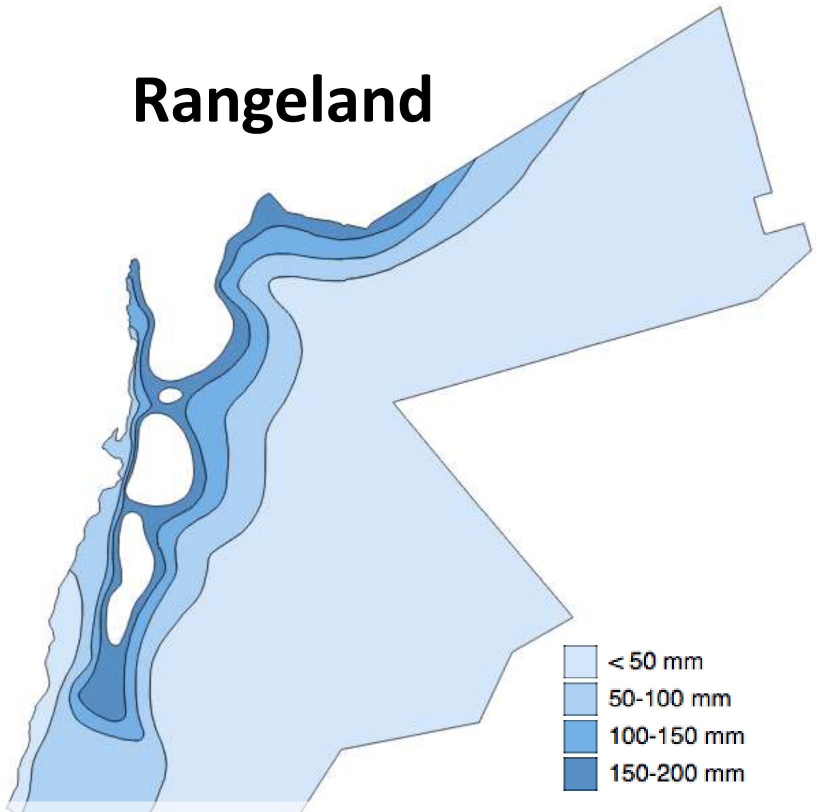
Impact of Rangeland Rehabilitation Strategies on Drought Resilience in Jordan

Definition of Terms

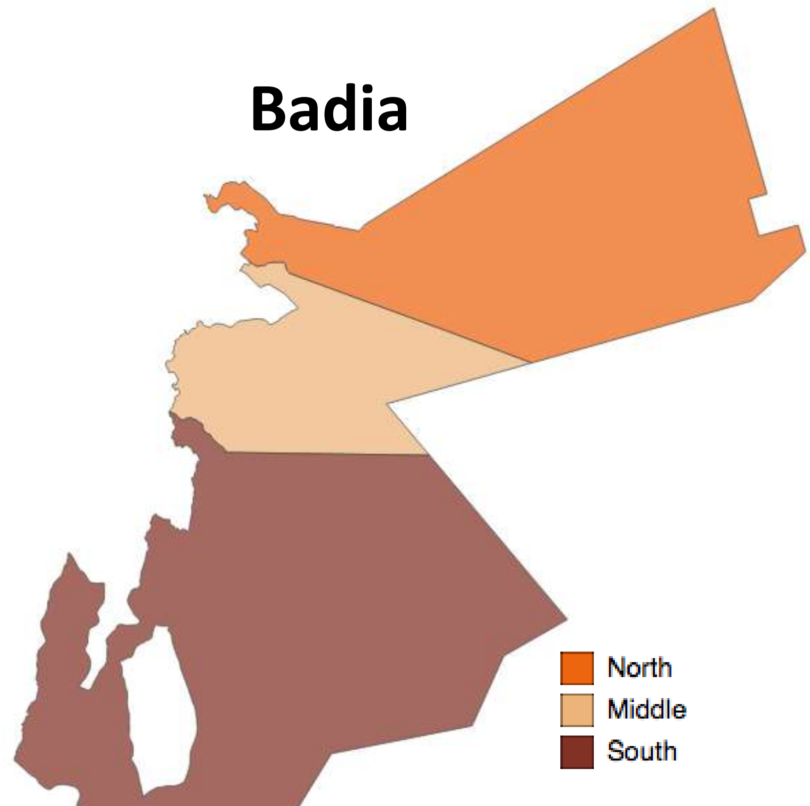
Rangeland



State-owned land that receives less than 200mm of rainfall annually

- Agriculture Law 20 (1970)

Badia



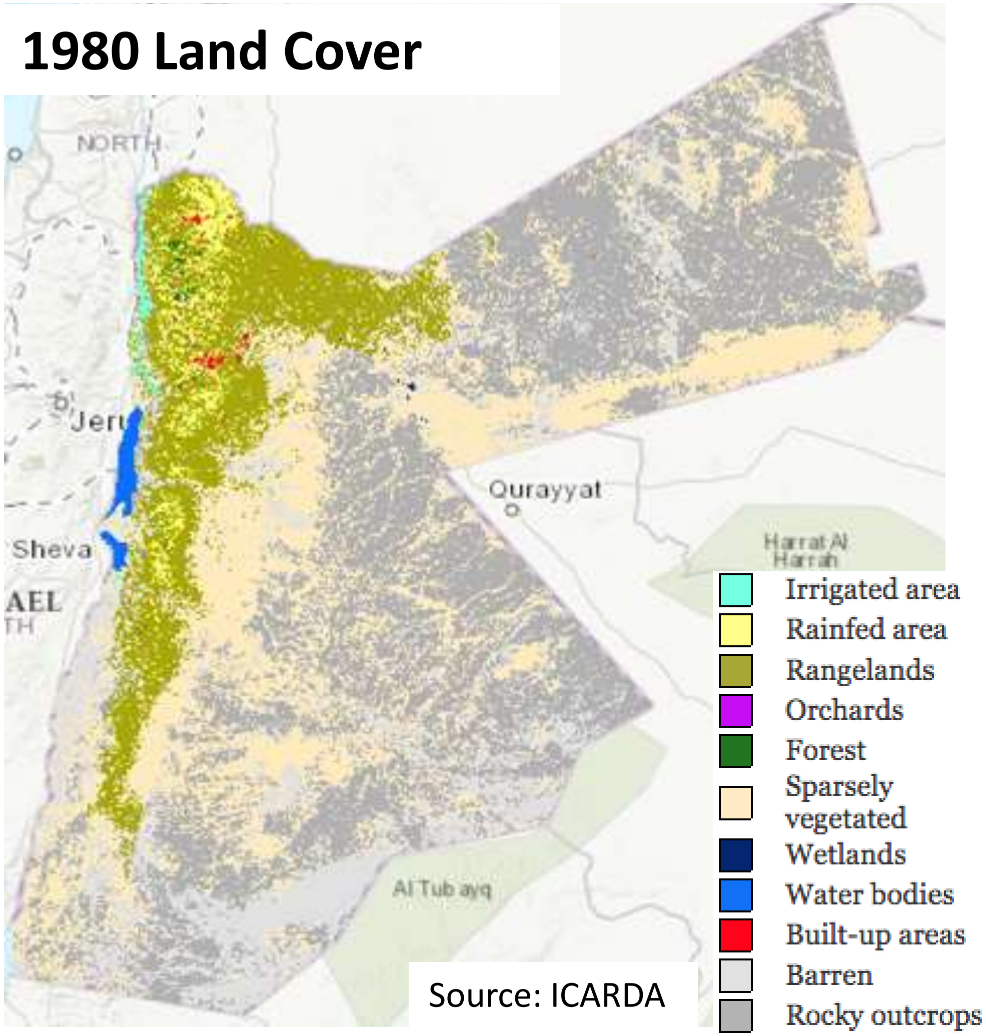
Administrative borders where the Bedouin communities reside

Data Source: Badia Restoration Project

Degradation of the Rangeland

Ecosystem services…

- Livestock fodder
- Medicinal herbs
- Wildlife biodiversity
- Groundwater recharge



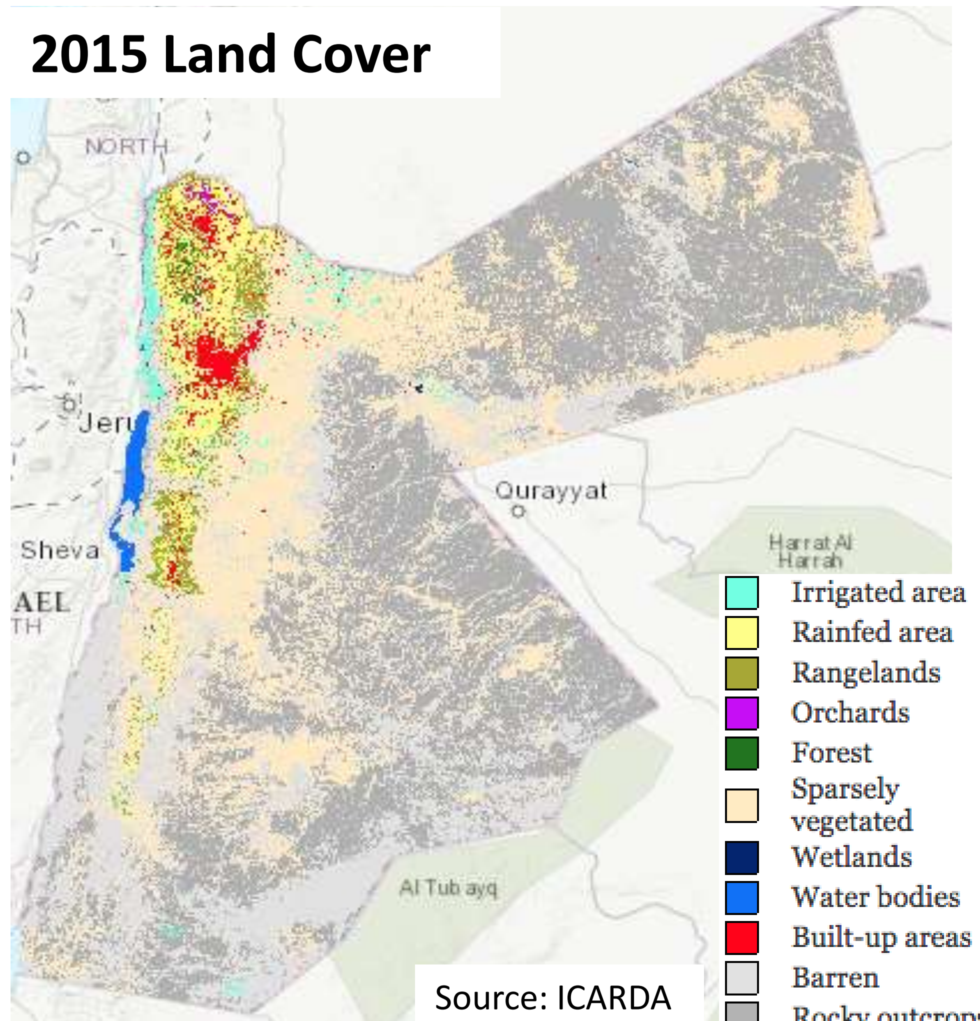
Degradation of the Rangeland

Ecosystem services…

- Livestock fodder
- Medicinal herbs
- Wildlife biodiversity
- Groundwater recharge

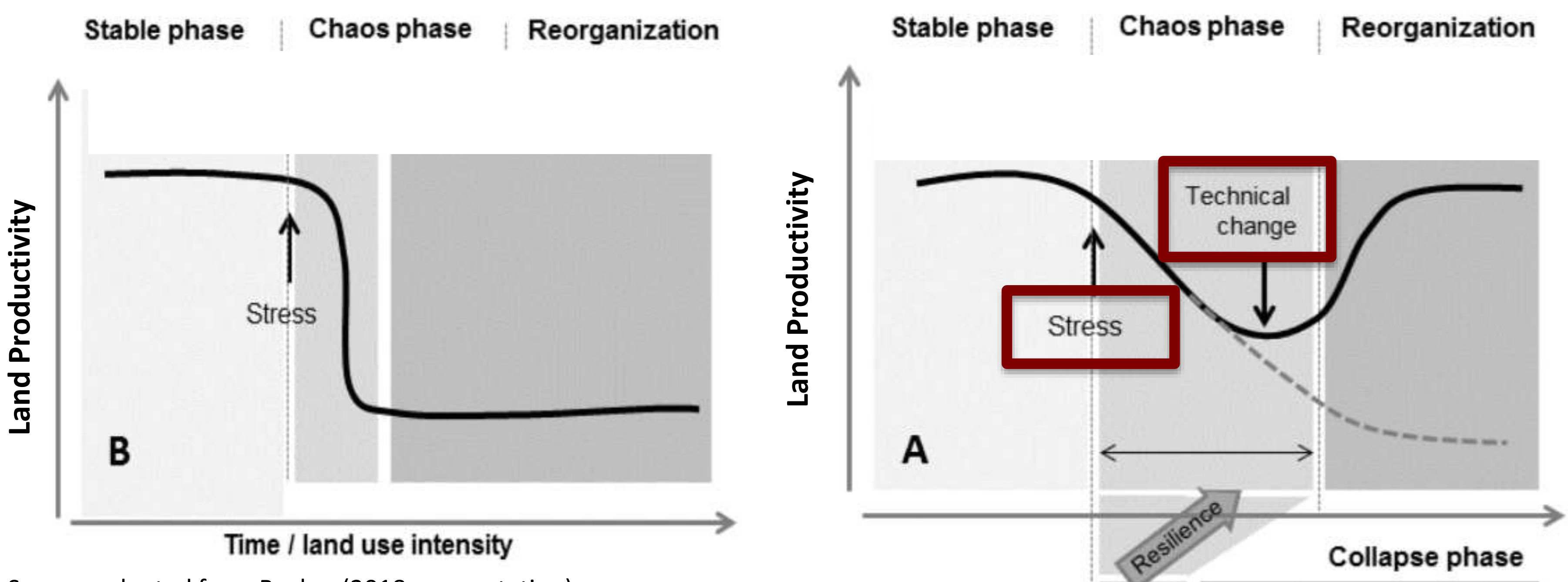
…have been degraded by:

- Overgrazing
- Land use changes
- Political boundaries
- Barley production
- Droughts



Social-Ecological Resilience

The ability to absorb shocks without restructuring or collapsing is linked to the status of ecosystem services and natural resources (Holling, 1973)



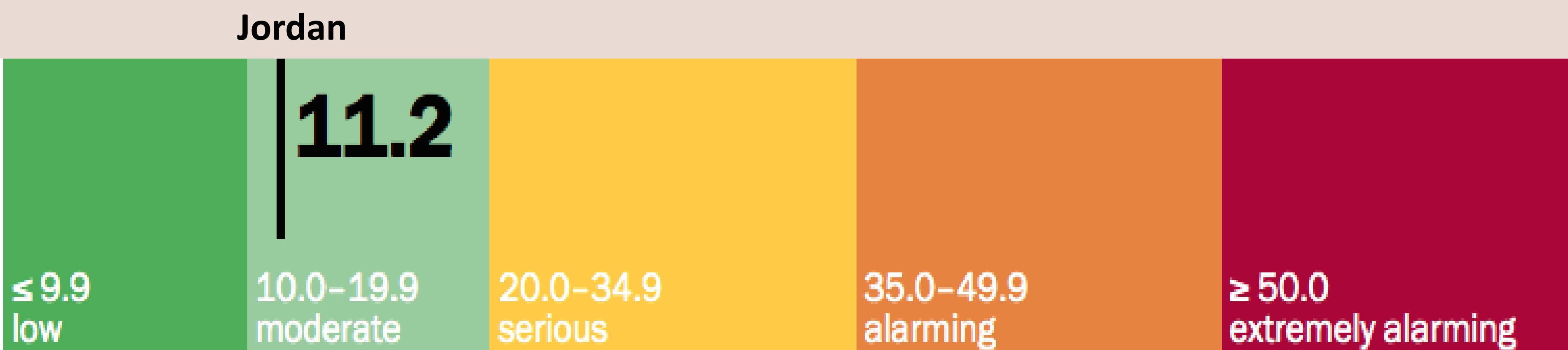
Source: adapted from Becker (2018, presentation)

Food Security in Jordan

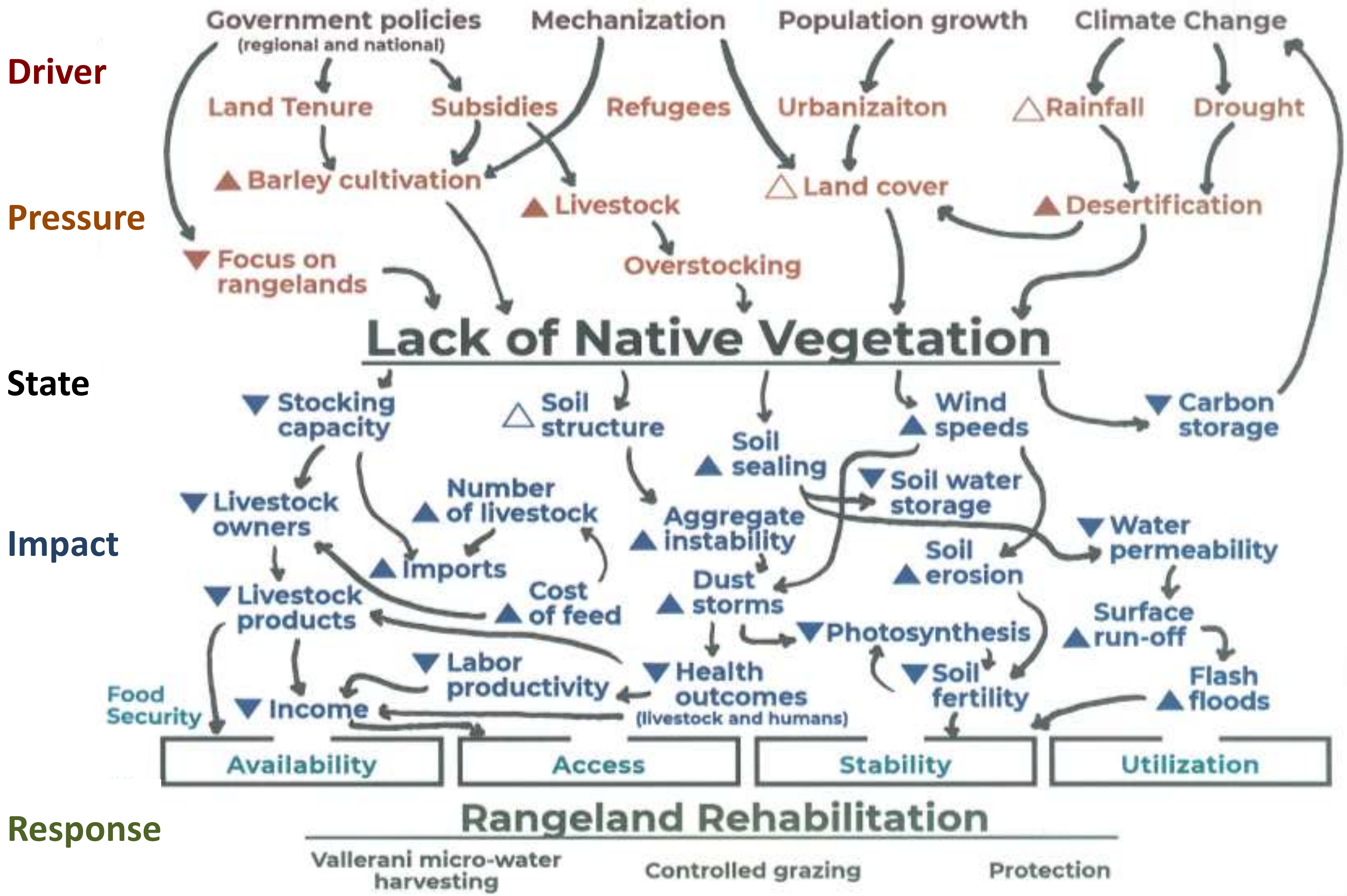
Global rankings are positive…

World Bank Classification	Upper middle income
Human Development Index	0.735 (#95 worldwide)
Global Hunger Index	11.2 (moderate)

Global Hunger Index Scale:



eDPSIR Framework



Focus on Droughts

Current water situation:

- 135m^3/year water per capita
- Below "absolute scarcity" threshold

Source: UNU – UN News

Source: Jordan Times/Osama Aqarbeh

Focus on Droughts

Current water situation:

- 135m^3/year water per capita
- Below “absolute scarcity” threshold

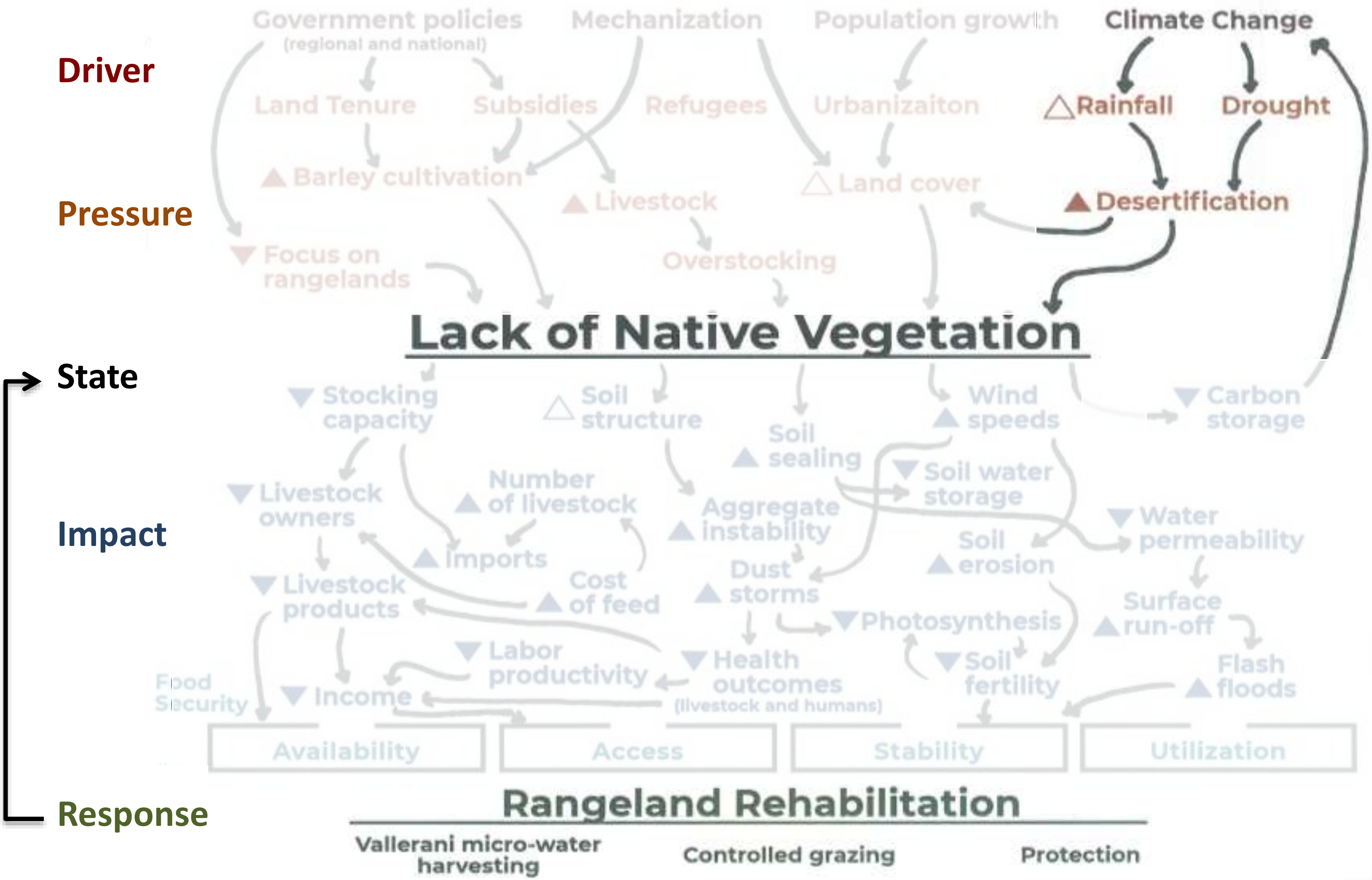
Future scenarios in 2070:

- Decrease in Syria to Jordan transboundary flow
- 30% reduction in rainfall
- Increase in extreme drought events to ~25 in 30 years

Source: UNU – UN News

Source: Jordan Times/Osama Aqarbeh

eDPSIR Framework



Management Strategies

Protected

Controlled Grazing

+ Protected

Vallerani

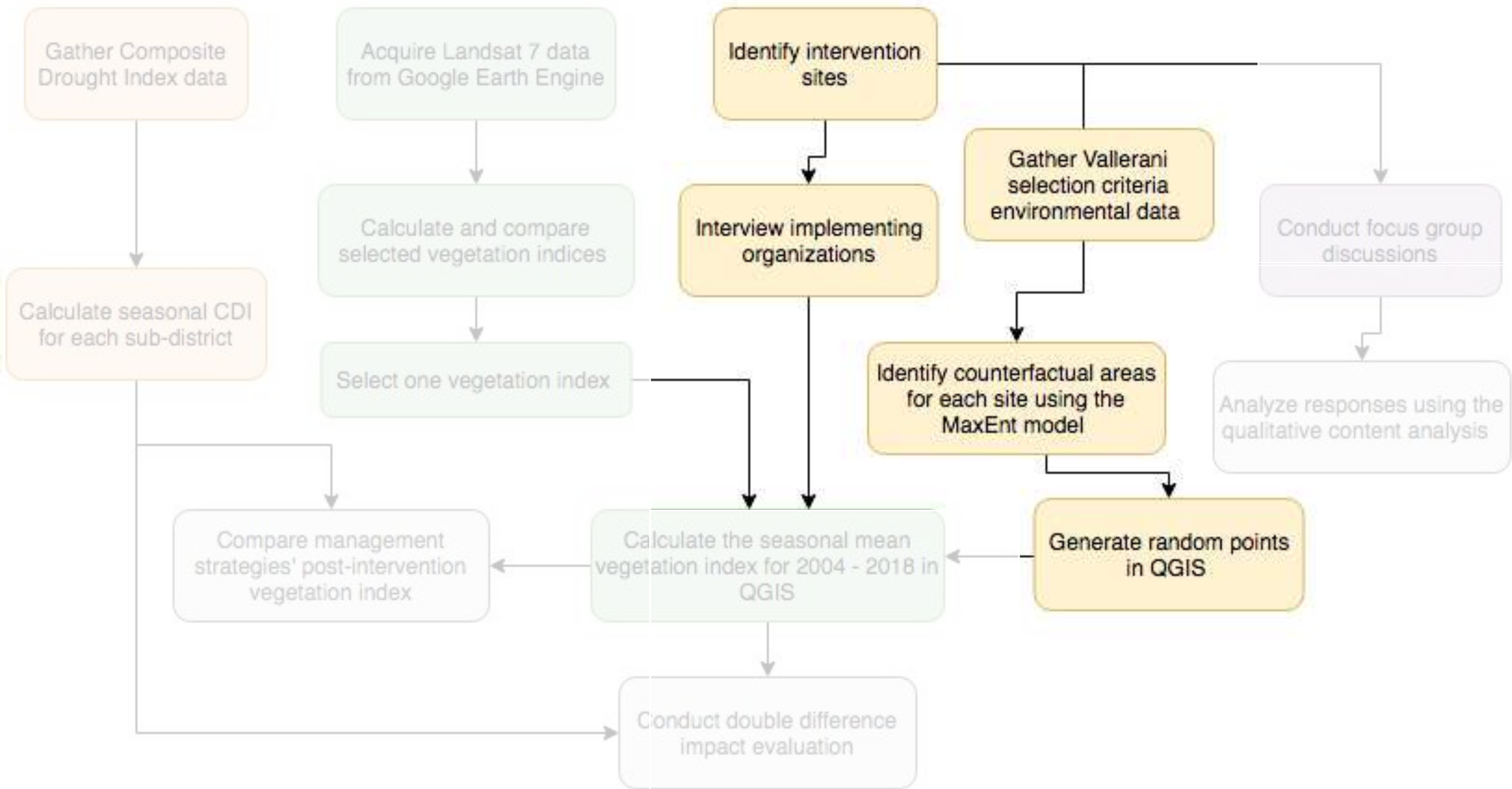
+ Protected
+ Controlled Grazing

Research Objectives

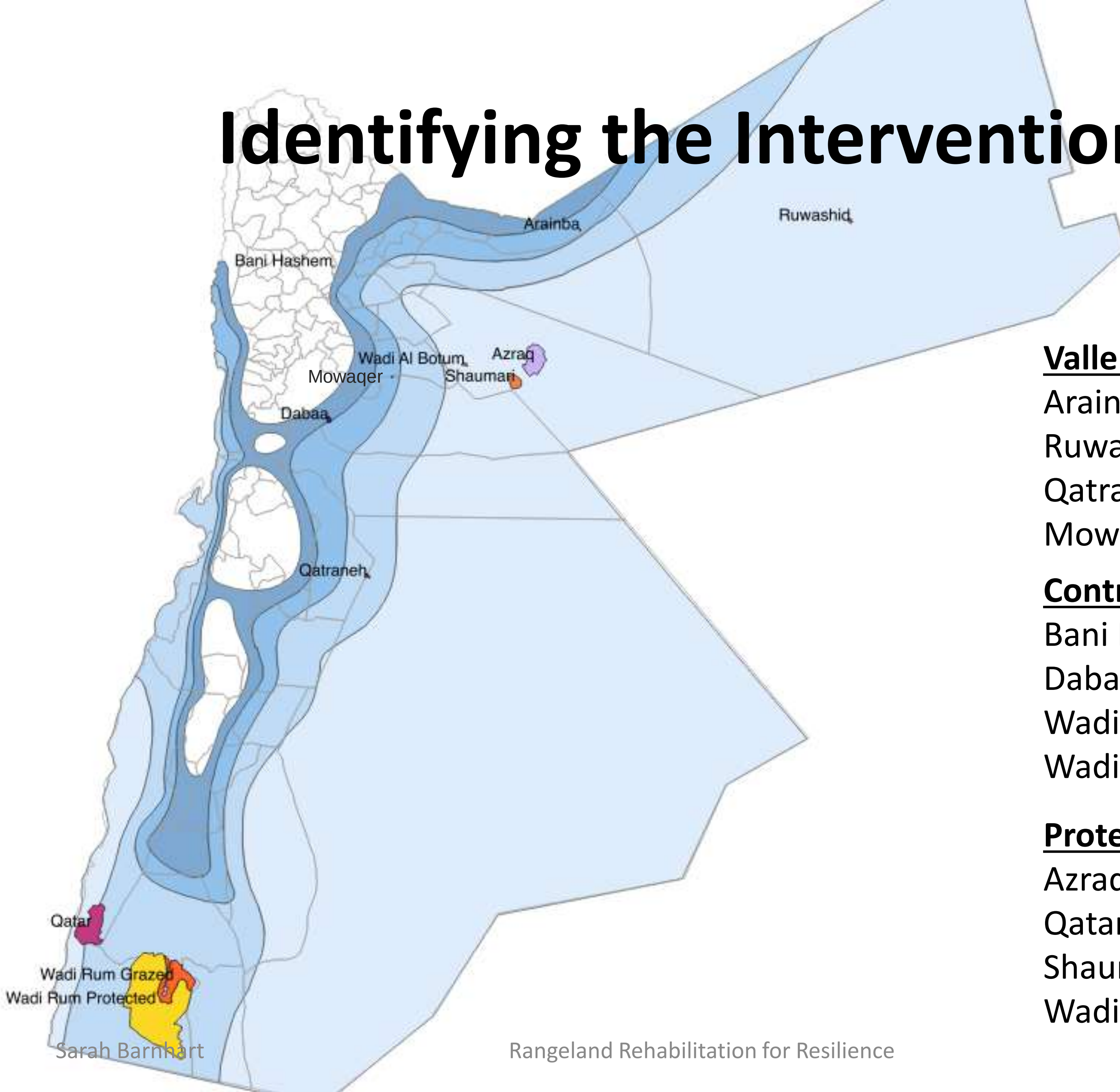
1. Analyze the effect of different rehabilitation strategies on vegetation cover
2. Assess the impact of rehabilitation interventions on ecological drought resilience
3. Understand how communities depend on the rangelands, cope with drought and perceive rehabilitation interventions



Identify Intervention Sites



Identifying the Interventions



Vallerani
Arainba
Ruwashid
Qatraneh
Mowaqer

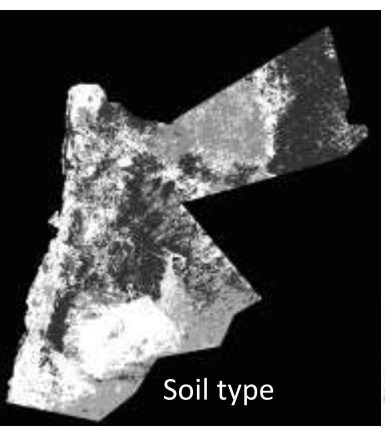
Controlled Grazing
Bani Hashem
Dabaa
Wadi Al Botum
Wadi Rum (use zone)

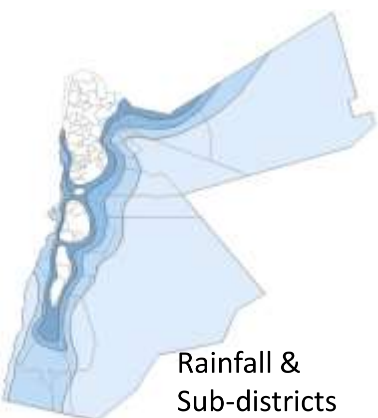
Protected
Azraq
Qatar
Shaumari
Wadi Rum

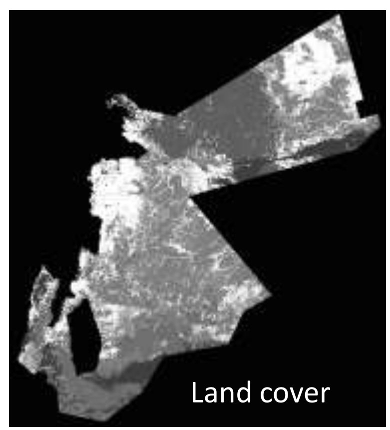
Generating Counterfactuals

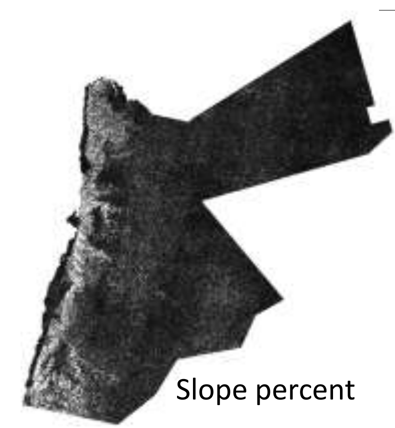
Maximum Entropy Model (MaxEnt) environmental input:

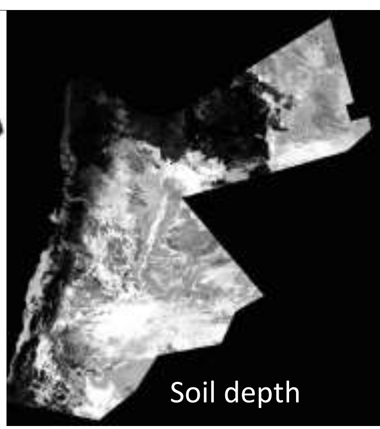
- Sub-district administrative borders (ICARDA)
- Slope percent (Alaska Satellite Facility)
- Annual rainfall (Badia Restoration Project)
- Dominant soil type (ISRIC)
- Soil depth to bedrock (ISRIC)
- Land cover (Badia Restoration Project)











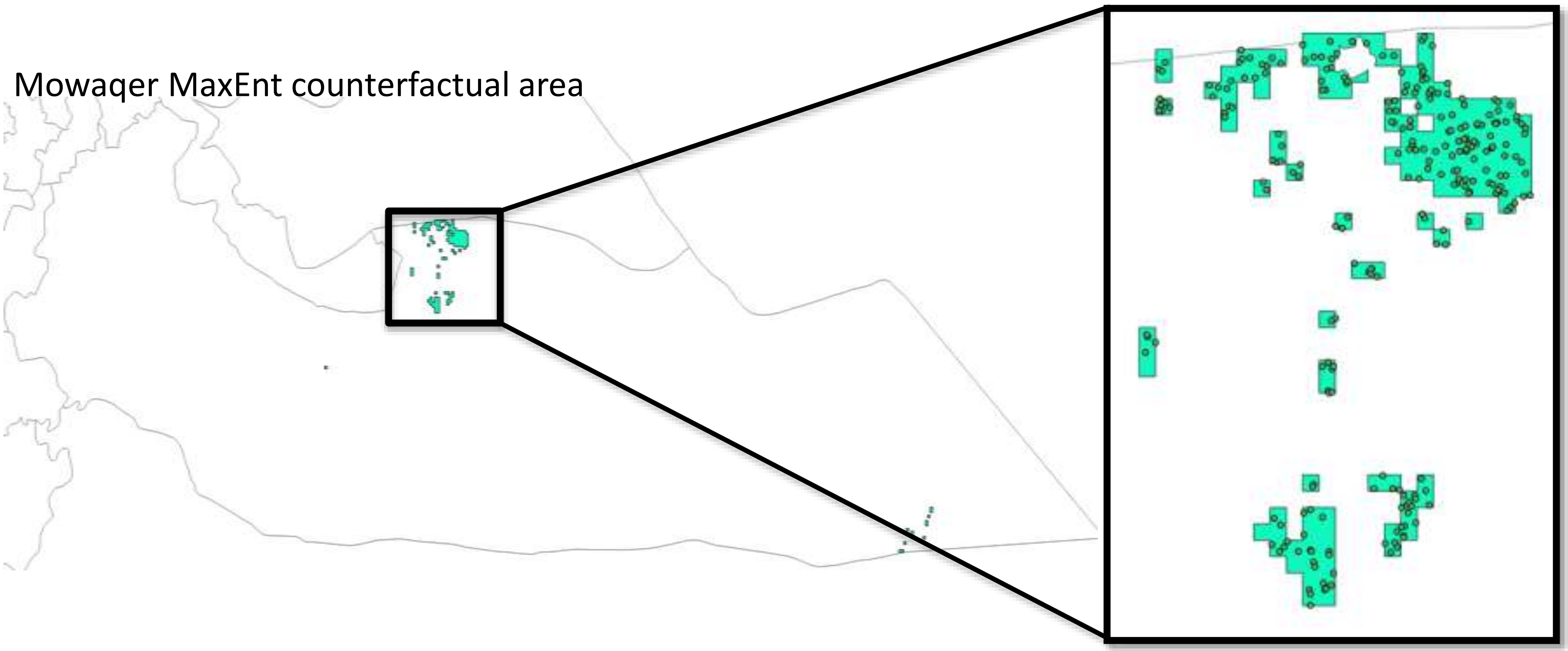
Generating Counterfactuals

Maximum Entropy Model (MaxEnt)

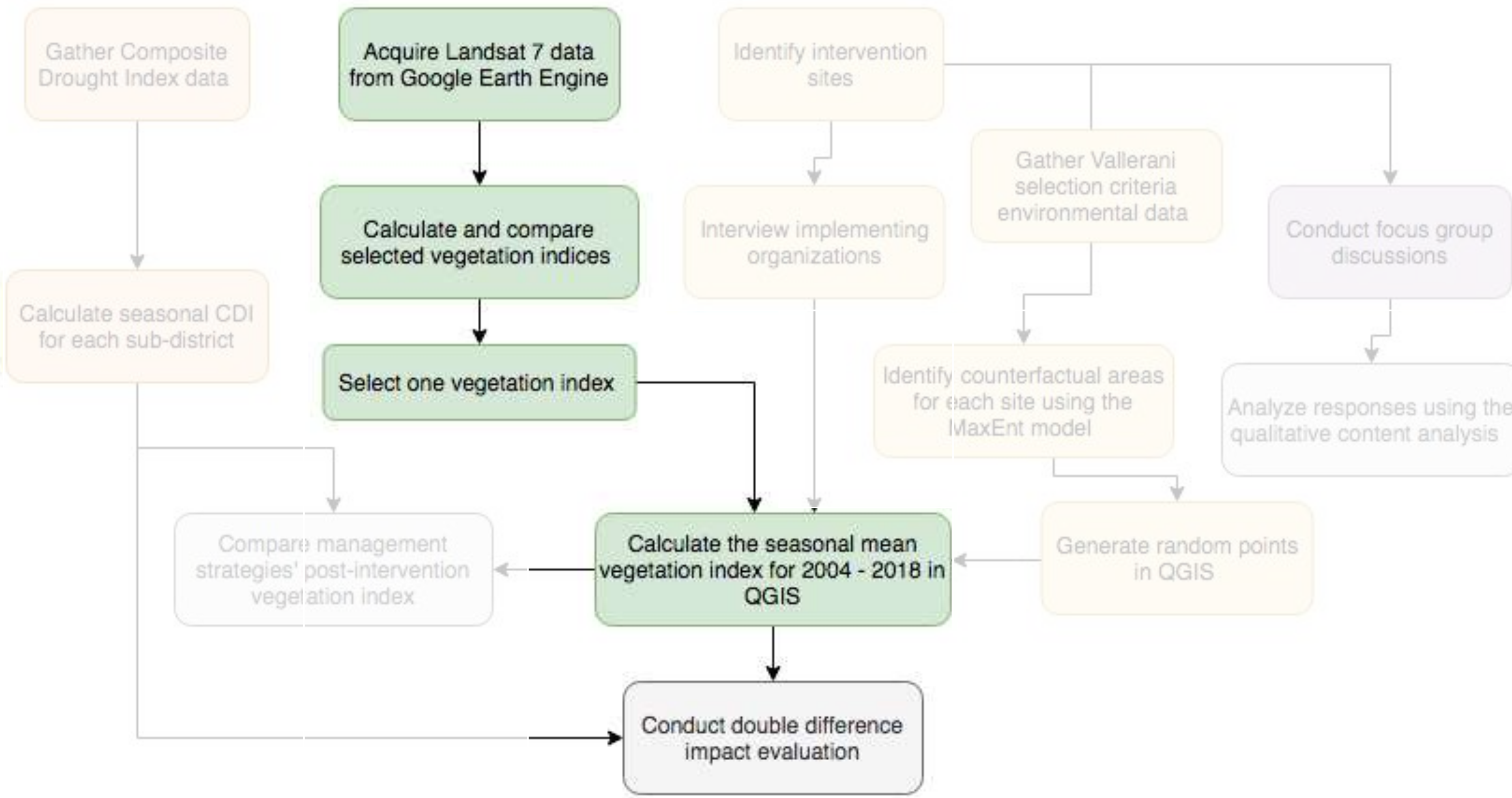
- Used to model species distribution

Mowaqer random points

Mowaqer MaxEnt counterfactual area



Identify Intervention Sites



Calculating Vegetation Indices

Enhanced Vegetation Index (EVI) II

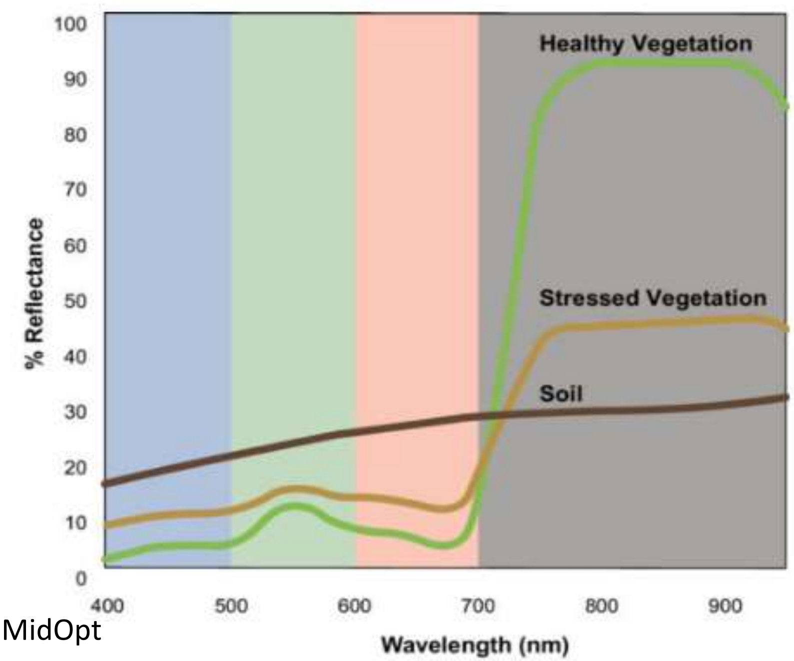
$$2.5 \times \frac{NIR - RED}{NIR + 2.4RED + 1}$$

Modified Soil Adjusted Vegetation Index (MSAVI) II

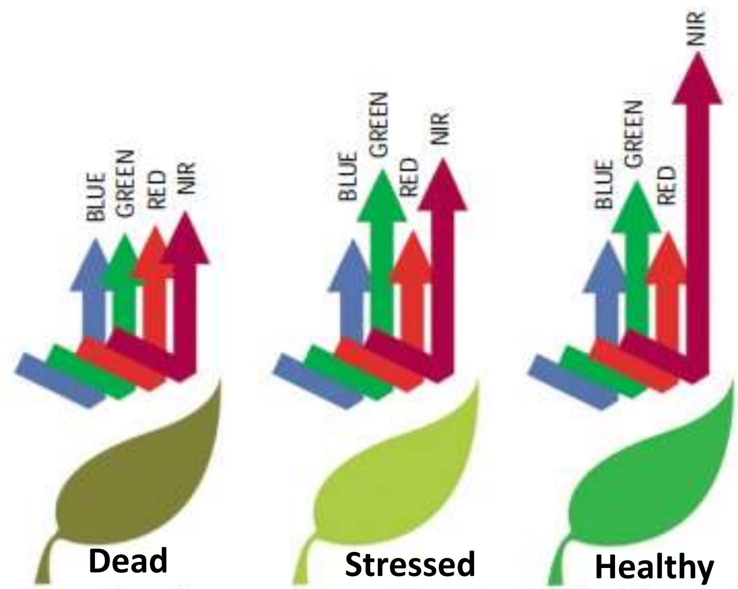
$$\frac{2NIR + 1 - \sqrt{(2 * NIR + 1)^2 - 8(NIR - RED)}}{2}$$

Normalized Difference Vegetation Index (NDVI)

$$\frac{NIR - RED}{NIR + RED}$$



Source: MidOpt

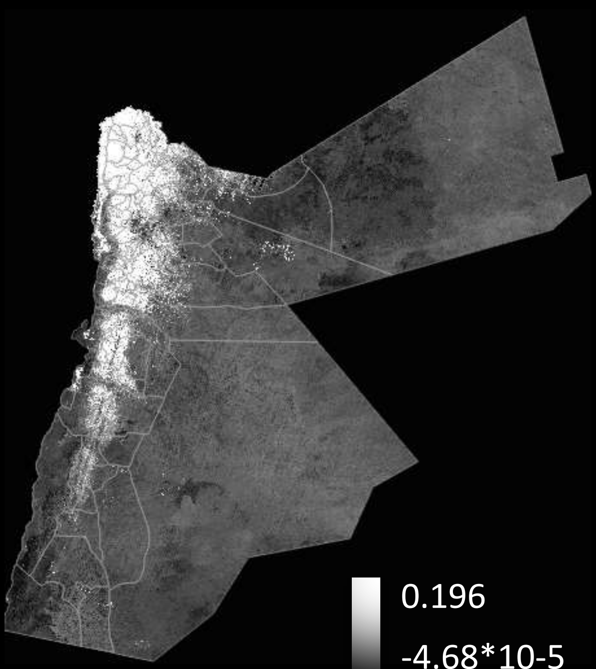


Source: Food and Agriculture Organization (FAO)

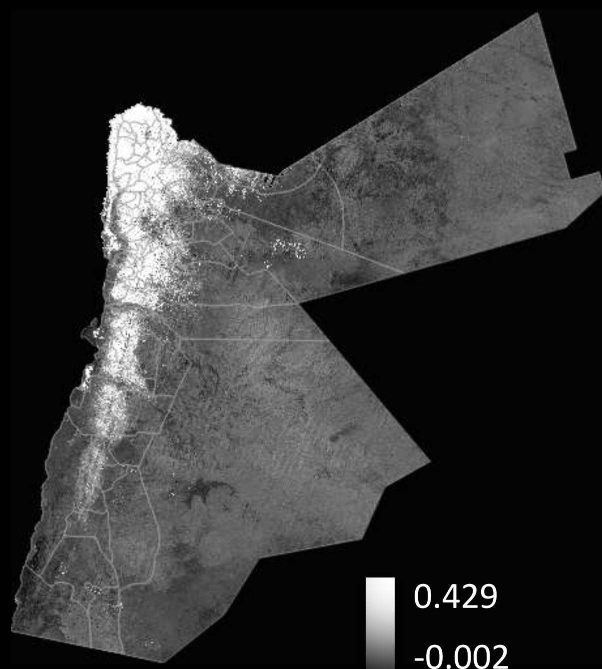
Composites from Landsat 7

January – March 2018

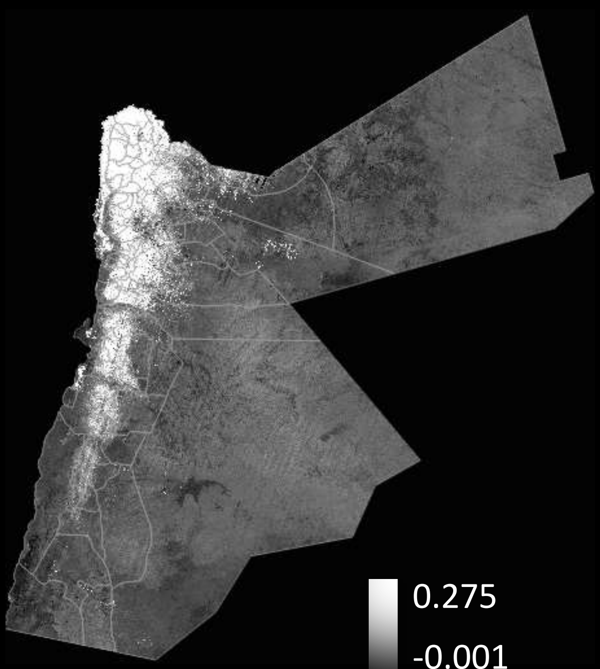
Enhanced Vegetation Index (EVI) II



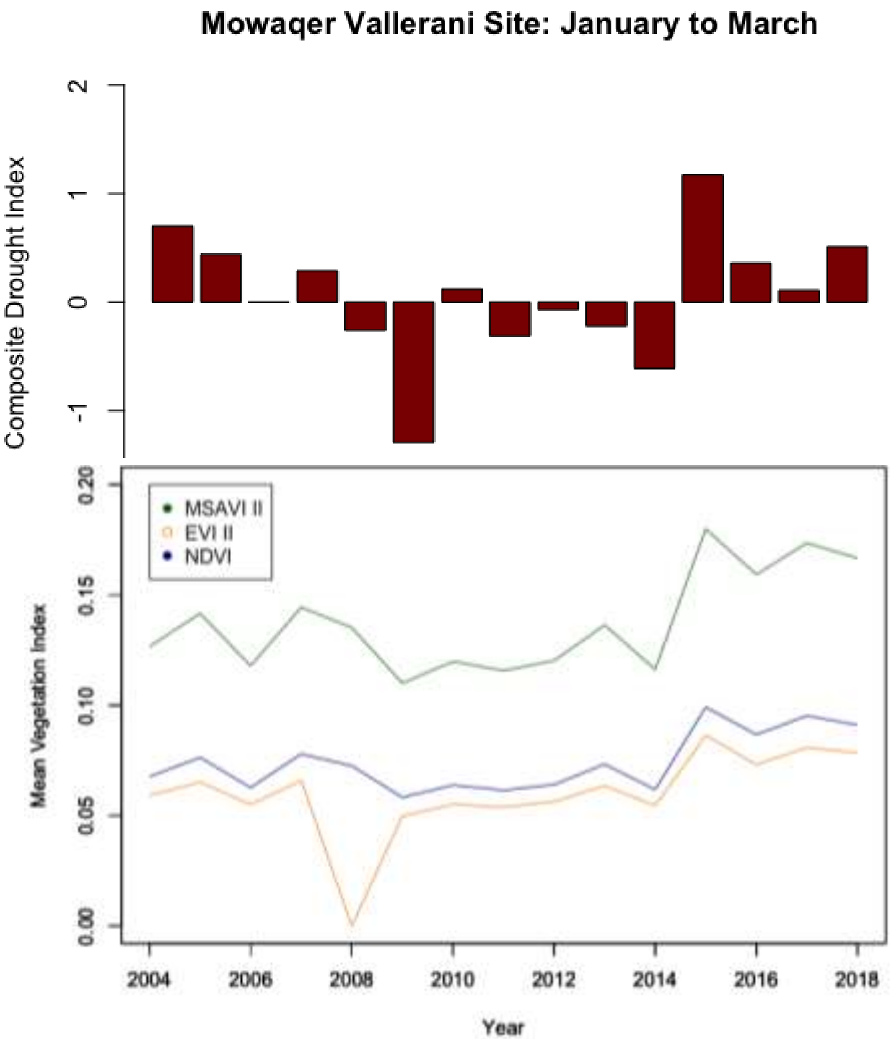
Modified Soil Adjusted Vegetation Index (MSAVI) II



Normalized Difference Vegetation Index (NDVI)



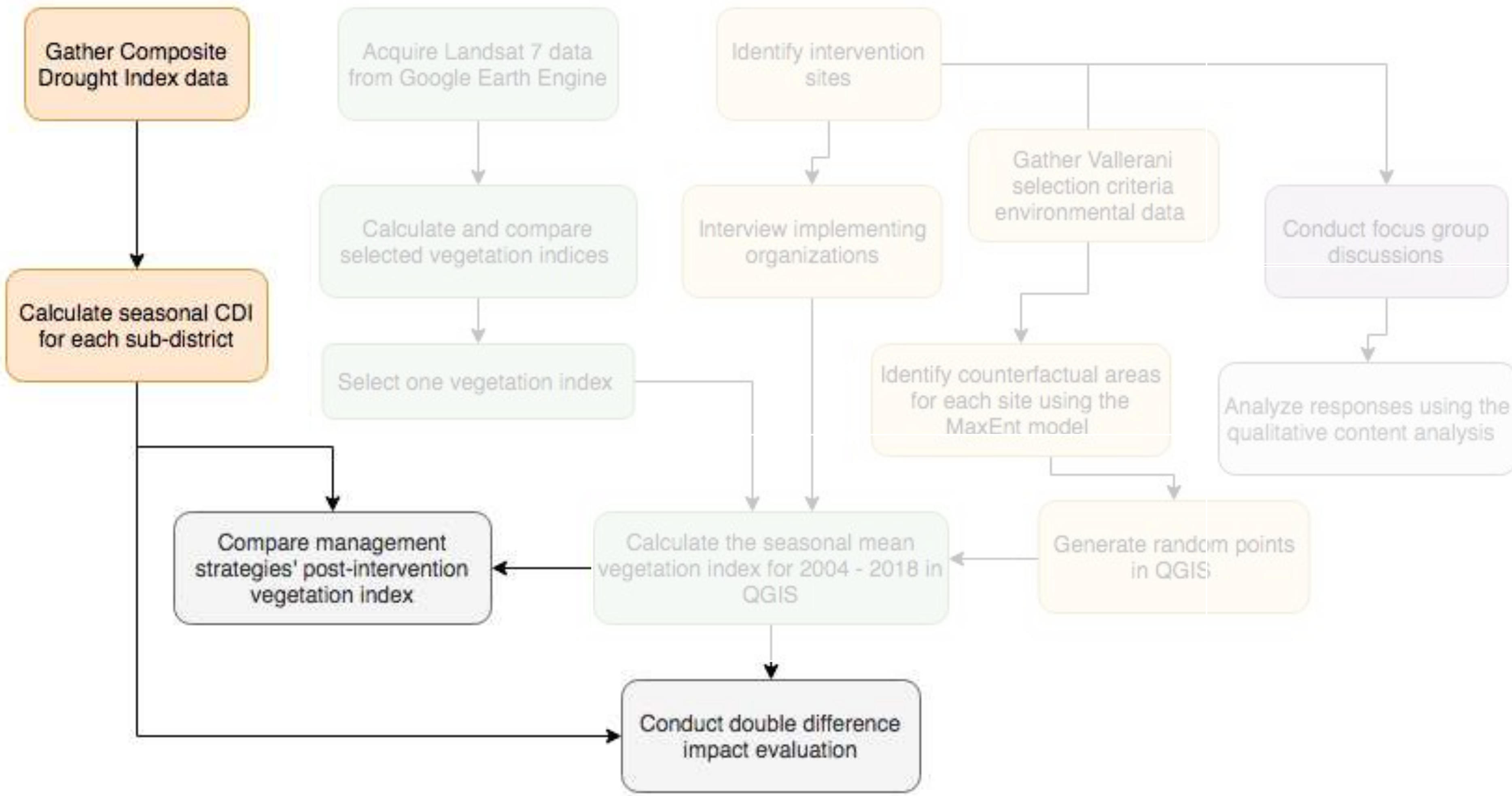
Assessing the Vegetation Indices



Similarity in vegetation index and CDI patterns

MSAVI II amplifies the vegetation signal

Identify Intervention Sites

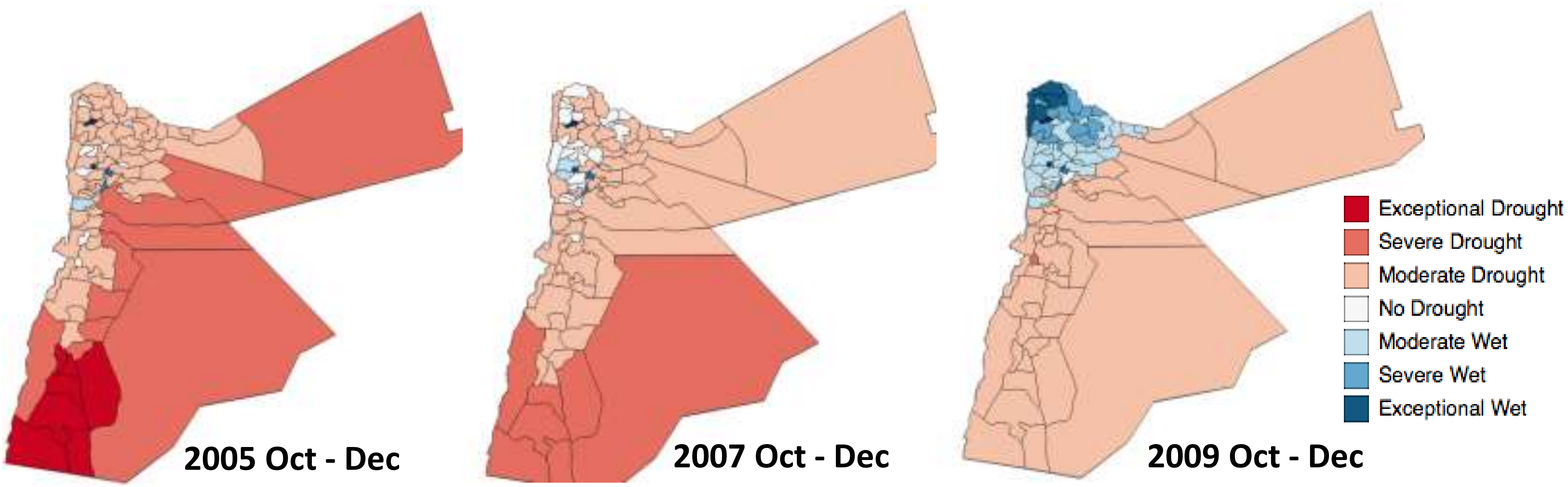


Classifying Drought

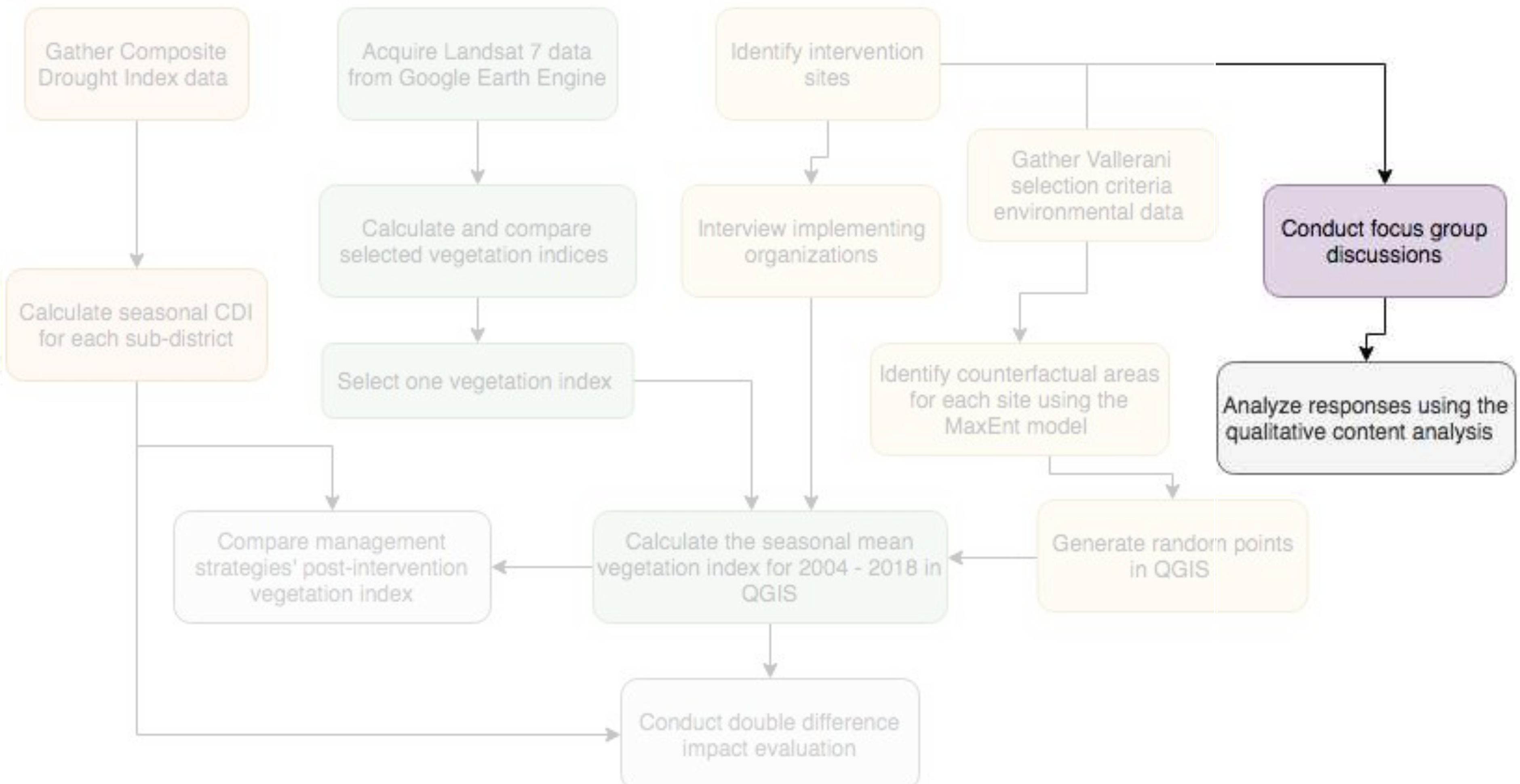
Monthly Composite Drought Index (Intl. Center for Biosaline Agriculture)

- Standardized Precipitation Index (SPI), monthly
- Normalized Difference Vegetation Index (NDVI), monthly
- Root zone soil moisture anomalies model
- Actual evapotranspiration
- Surface temperature anomalies

Three month rainy season averages (January – March, October – December)



Identify Intervention Sites



Integrating Qualitative Data

- Semi-grounded theory
- Focus group discussions
  - Four communities
  - 37 people (13 men, 24 women)
  - Gender segregated (mostly)
- Validated questions with aim to:
  - Understand how dependence on the rangeland changed
  - Identify drought coping strategies
  - Gather opinions about the value of rangeland rehabilitation

1. Analyze the effect of rehabilitation strategies on vegetation cover

Analyzing Vegetation Trends

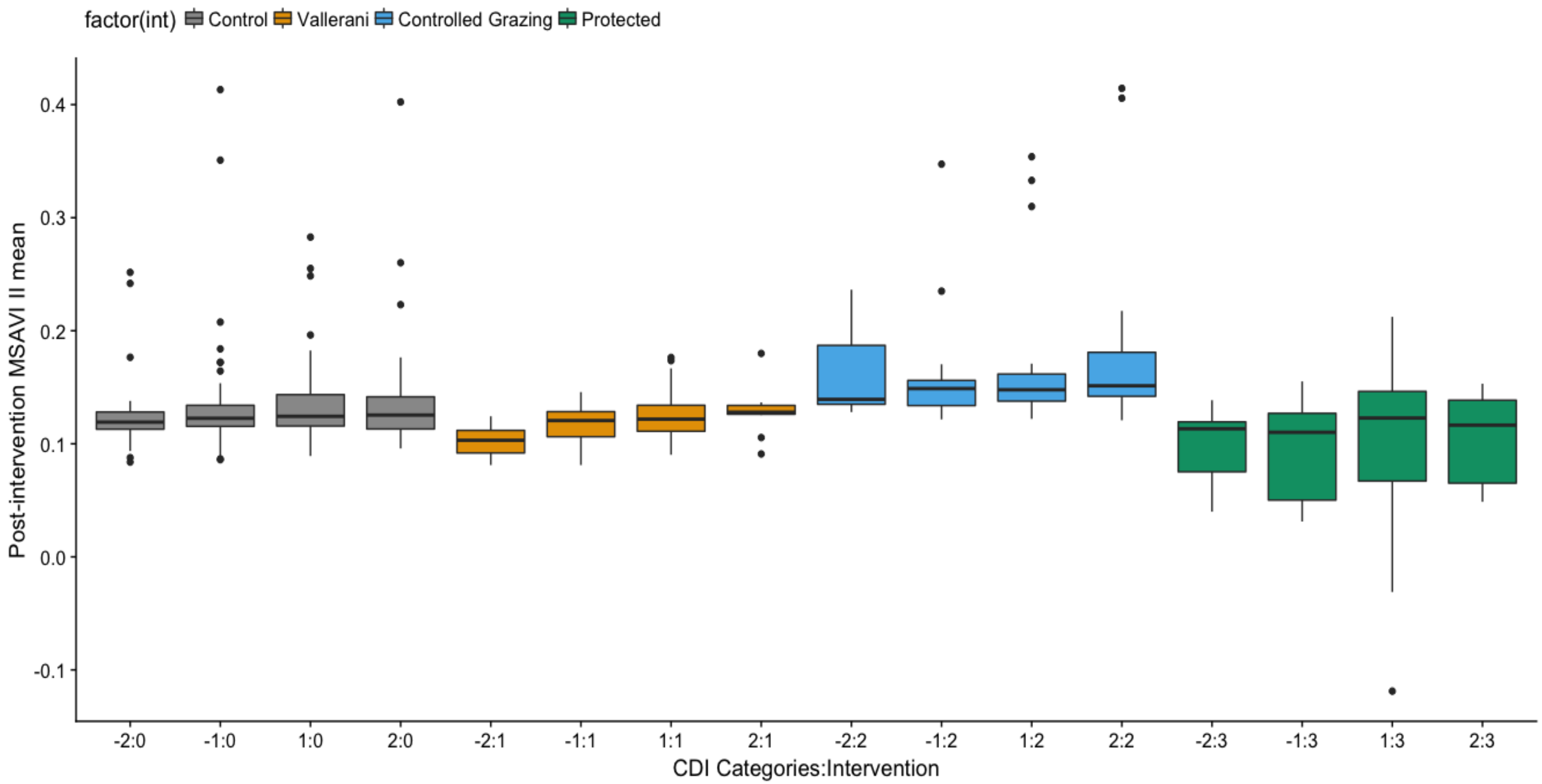
- Time trend analysis from 2004-2018
- Mann Kendall non-parametric test:

	January – March		October – December	
	Tau	*2-sided p-value*	*Tau*	*2-sided p-value*
Arainba	0.007	0.972	-0.103	0.43245
Azraq	-0.101	0.443	-0.159	0.22506
Bani Hashem	-0.054	0.694	-0.113	0.39179
Dabaa	0.425	0.0010279***	0.287	0.026947***
Mowaqer	0.324	0.012499***	0.062	0.64274
Qatar	0.059	0.69155	0.002	1
Qatraneh	-0.025	0.8584	0.099	0.45366
Ruwashid	0.186	0.1535	0.274	0.03527***
Shaumari	0.287	0.026947***	0.140	0.28441
Wadi Al Botum	0.356	0.0060048***	0.117	0.37237
Wadi Rum Grazed	0.568	0.000011444***	0.425	0.0010279***
Wadi Rum Protected	0.430	0.00090528***	0.264	0.041964***

Controlled grazing sites have the most significant, positive vegetation cover trends

Comparing the Strategy Outcomes

Post-intervention data only



Comparing the Strategy Outcomes

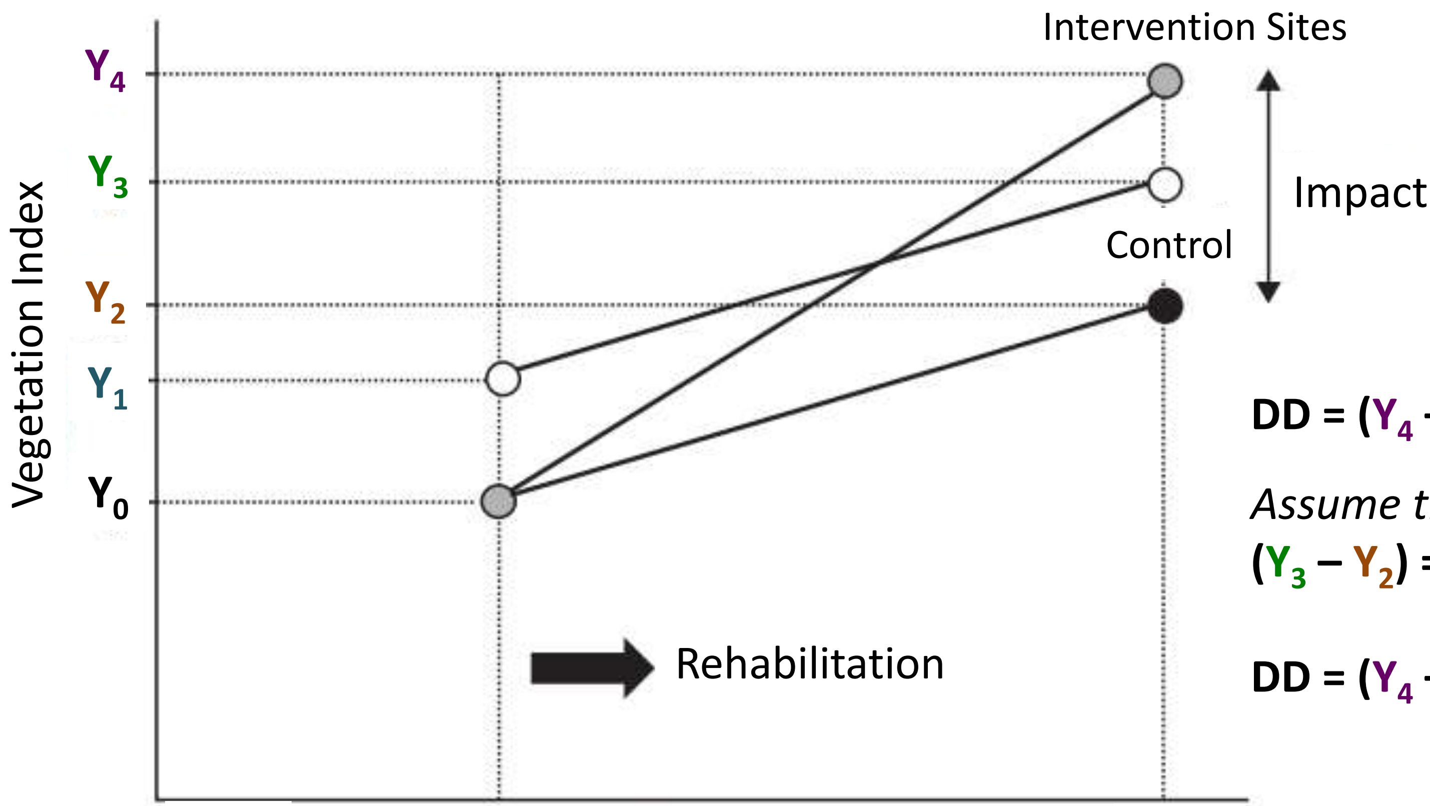
Post-intervention data only

Unbalanced, three-way ANOVA (type II):

Variable	Sum Sq	Df	F value	Pr(>F)
Treatment	0.186	3	31.735	$2.2*10^{-16}$ ***
CDI Category	0.018	3	3.126	0.026 *
Season	0.054	1	27.762	$2.15 * 10^{-7}$***
Treatment: CDI Category	0.009	9	0.527	0.855
Treatment: Season	0.026	3	4.496	0.004**
CDI Category: Season	0.006	3	1.028	0.380
Treatment: CDI Category: Season	0.011	9	0.636	0.766
Residuals	0.858	440		

Vegetation cover is significantly impacted by the intervention strategy and the interaction with the season

Calculating the Double Difference



DD = ($Y_4 - Y_0$) - (Y_3 - Y_1)

Assume that:

($Y_3 - Y_2$) = ($Y_1 - Y_0$)

DD = ($Y_4 - Y_2$)

Assessed Vallerani and Controlled Grazing interventions

Source: adapted from Khandker *et al*. (2010)

Calculating the Double Difference

Simple calculation:

Season	Vallerani	Controlled Grazing
January - March	-0.004	0.005
October – December	-0.003	-0.002
Overall	-0.003	0.002

No change between the counterfactual and intervention sites

Ordinary Least Squares regression (tt = treatment *time):

Season	Coefficient	Estimate	Std. Error	t-value	Pr(>|t|)
Jan-Mar	(Intercept)	0.171	0.010	17.049	$2 * 10^{-16}$**
	Tt (interaction)	-0.001	0.020	-0.061	0.951
	Treatment	-0.003	0.014	-0.242	0.809
	Time	-0.002	0.014	-0.170	0.865
Oct-Dec	(Intercept)	0.134	0.004	37.27	$2 * 10^{-16}$**
	Tt (interaction)	-0.003	0.007	-0.426	0.671
	Treatment	-0.002	0.005	-0.412	0.681
	Time	-0.001	0.005	-0.146	0.884

No significant differences

2. Assess the impact of rehabilitation on ecological drought resilience

Correlating with Drought

Post intervention data only

Spearman's correlation of MSAVI II means and CDI

Treatment	Correlation
Untreated	0.134
Overall Treated	0.208
Vallerani	0.289
Controlled Grazing	0.152
Protected	0.193

The intervention sites are influenced by drought more than untreated areas

Panel Fixed Effects Model

$$Y_{it} = \emptyset T_{it} + \delta X_{it} + \eta_i + \varepsilon_{it}$$

$$\Delta Y_{it} = \phi \Delta T_{it} + \delta \Delta X_{it} + \Delta \varepsilon_{it}$$

Outcome

Treatment

Observable, time variant characteristics

Unobserved, time invariant characteristics

where: t = time dummy (0,1)
i = treatment dummy (0,1)

Assessing the OLS Fixed Effects

January – March:

	Estimate	Std. Error	t-value	Pr(>|t|)
Intercept	0.1710983	0.0100155	17.0834	$2.2*10^{-16}$ **
tt (interaction)	-0.0012042	0.0203680	-0.0591	0.9529
Treatment	-0.0034972	0.0142293	-0.2458	0.8061
Time	-0.0037798	0.0143950	-0.2626	0.7931
CDI	0.0112830	0.0073178	1.5419	0.1247

Total Sum of Squares:	1.1191
Residual Sum of Squares:	1.1048
R-Squared:	0.012742
Adj. R-Squared:	-0.0066162
F-statistic:	0.658217 on 4 and 204 DF
p-value:	0.62173

October – December:

	Estimate	Std. Error	t-value	Pr(>|t|)
Intercept	0.1353865	0.0036193	37.4067	$2.2*10^{-16}$ **
tt (interaction)	-0.0030456	0.0070924	-0.4294	0.66807
Treatment	-0.0020944	0.0050389	-0.4156	0.67811
Time	-0.0037793	0.0052049	-0.7261	0.46860
CDI	0.0042540	0.0019480	2.1837	0.03012*

Total Sum of Squares:	0.13956
Residual Sum of Squares:	0.13533
R-Squared:	0.030312

Droughts from October to December impact vegetation cover more than January to March

Testing Serial Correlation

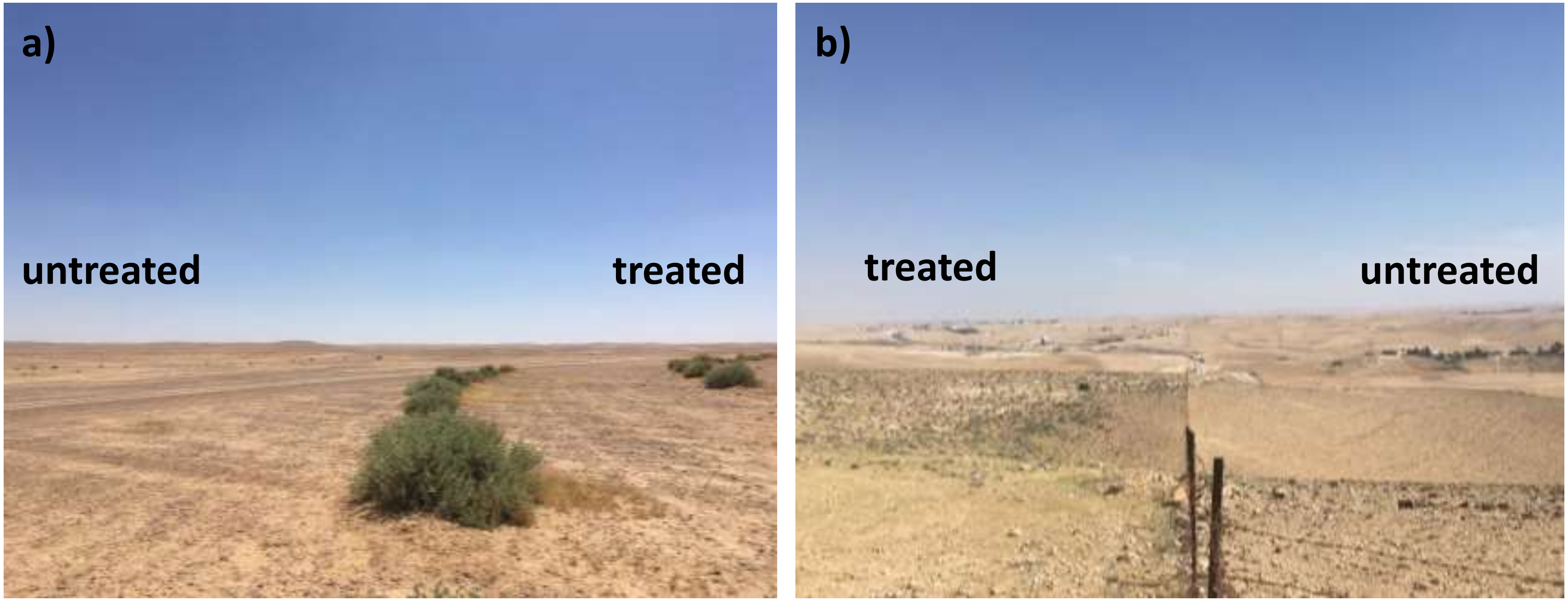
Durbin Watson Results:

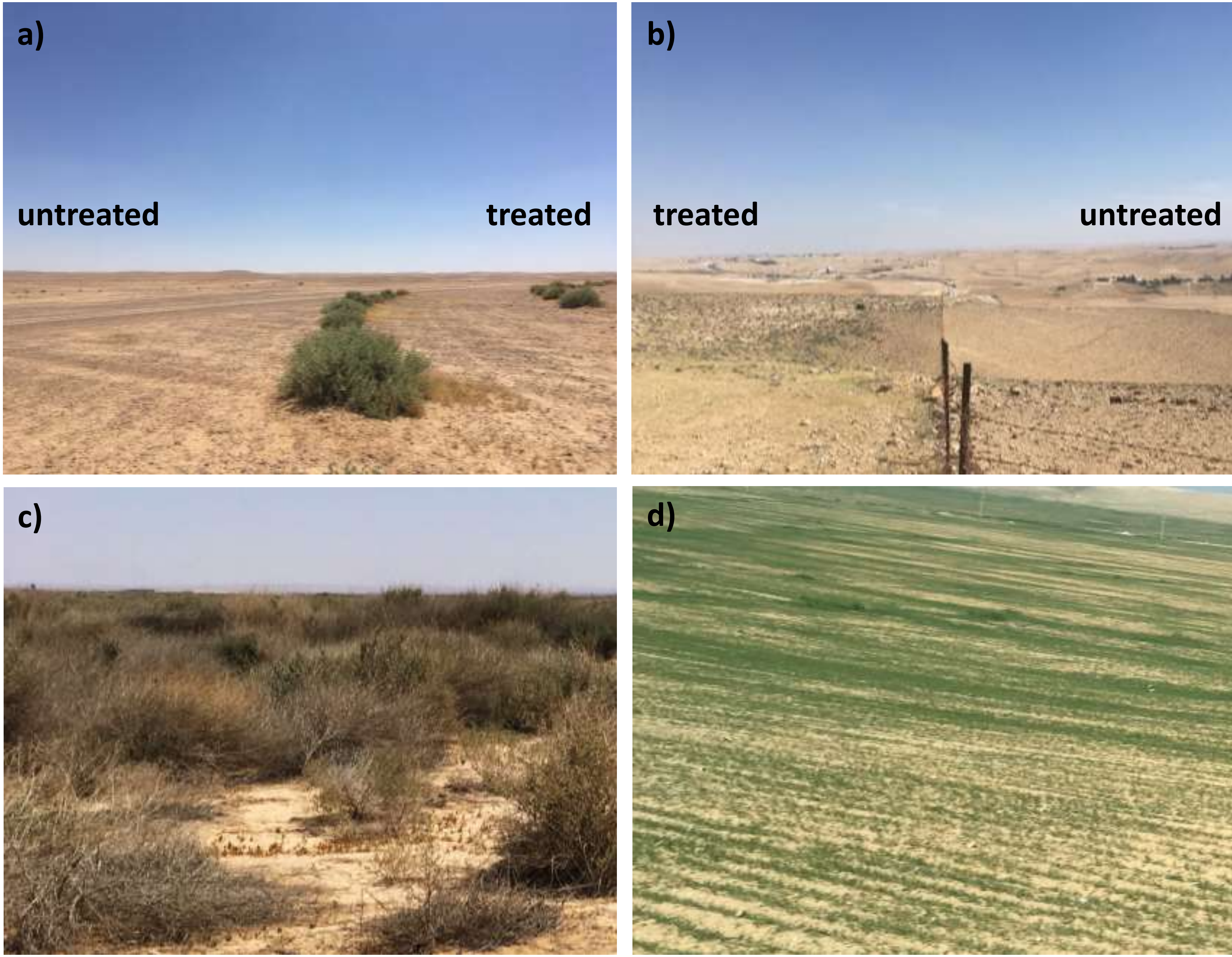
	January – March	**October – December**
Autocorrelation	0.749	0.798
D-W statistic	0.495	0.373
P-value	0	0

Null hypothesis (residuals are not auto correlated) is accepted, but the autocorrelation is less than 1?

Sustainable or Unsustainable "Green"?

- Rehabilitation or not, vegetation cover is similar
  - Sustainability of barley and irrigated agriculture?
  - Incorporation of input costs




a)
untreated
treated
b)
treated
untreated
c)
d)

3. Understand how communities depend on rangelands, cope with drought and perceive rehabilitation

Common Themes from Discussions

	Azraq (M; n=8)	Azraq (W; n=3)	Qatraneh (M; n=6 W; n=1)	Bani Hashem (W; n=12)	Jaber (W; n=8)	Total
ES. Provisioning ecosystem services	4	6	5	4	2	21
ES. Regulating ecosystem services	2	0	2	0	0	4
ES. Supporting ecosystem services	1	0	0	0	0	1
DR. Anthropogenic drivers	1	0	1	1	1	4
DR. Natural drivers	6	3	3	2	2	16
IM. Poor animal health	0	1	0	3	1	5
IM. Climatic changes	2	0	0	0	1	3
IM. Economic hardship	1	2	8	5	5	21
IM. Change in rangeland dependence	2	2	1	2	3	9
IM. Negative effect on ecosystem services	7	6	4	3	6	26
IM. Pressure on social systems	0	0	1	2	0	3
CS. Buy livestock products	0	1	1	1	1	4
CS. Transition away from pastoralism	7	4	2	4	5	22
CS. Intensification of agriculture	0	1	2	0	4	6
CS. Alternative resources for livestock	3	0	3	0	5	10
RP. Interest in renewing the rangeland	2	2	1	0	5	10
Cooperative management	0	0	0	0	1	1
Education of rangeland benefits	0	0	0	0	1	1
Target interventions	2	0	0	0	0	2
Coordinate investments	0	0	1	0	0	1
RP. Knowledge of intervention strategies	3	1	5	2	1	12
RP. Alternative livelihood options	0	0	0	1	0	1
Job creation for women	0	0	0	1	0	1
RP. Idealization of the past	1	1	0	0	1	3
SUM	**44**	**30**	**39**	**31**	**46**	**190**

Constant Comparison Analysis

- Highlighted provisioning ecosystem services (ES)
  - Forage for livestock
  - Medicinal herbs

Constant Comparison Analysis

- Highlighted provisioning ecosystem services (ES)
  - Forage for livestock
  - Medicinal herbs
- Identified natural and human drivers of degradation
  - Drought and reduced rainfall

…with the exception of this year!

Constant Comparison Analysis

- Highlighted provisioning ecosystem services (ES)
  - Forage for livestock
  - Medicinal herbs
- Identified natural and human drivers of degradation
  - Drought and reduced rainfall
- Decreased rangeland dependence

Jordan Times

7iber

Constant Comparison Analysis

- Highlighted provisioning ecosystem services (ES)
  - Forage for livestock
  - Medicinal herbs
- Identified natural and human drivers of degradation
  - Drought and reduced rainfall
- Decreased rangeland dependence
- Common coping strategies:
  - Transition away from pastoral livelihoods
  - Urbanization
  - **Intensification of agriculture**

Policy Implications

- Include cost of rainfed barley cultivation and irrigated agriculture
  - Ecosystem service valuation
  - Inputs (seed, tractor, fuel, etc.)
  - Over abstraction of water
- Invest in rangelands
  - Livelihood alternatives are unsustainable or limited
  - Externalities (health, infrastructure, etc.)

Recommendations for Future Studies

- Improve counterfactual site identification to account for barley and other agriculture
    - Use finer resolution land cover data
    - Include land tenure data (public vs. private land)
- Compare remote sensing data with field samples
- Utilize higher resolution vegetation index data
    - Sentinel 2 (2015 – onwards)
- Select sites with more detailed records and controls

Monitoring for Impact

Long-term monitoring of rehabilitation interventions is

t to drivers of

ods