

國立中興大學

National Chung Hsing University

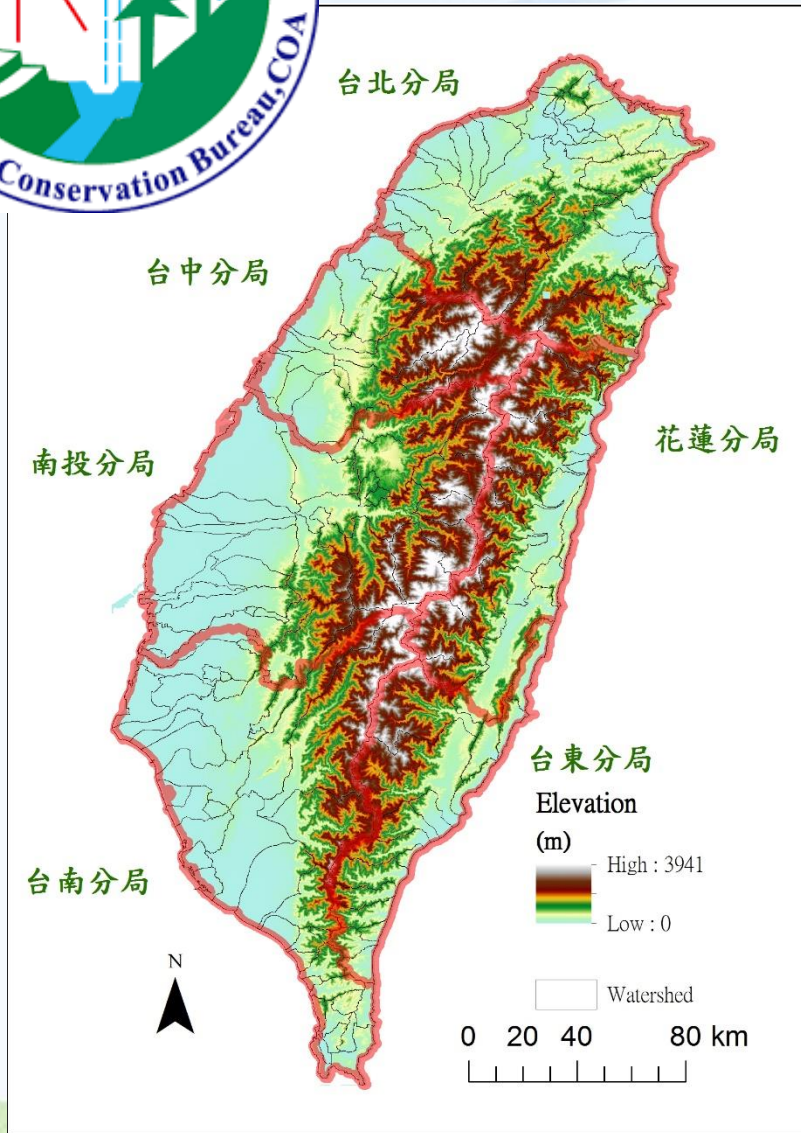
應用30年遙測資料調整 上游集水區氣候變遷調適策略

Adjusting climate change adaptation
strategies for upstream watershed using
30 years remote sensed data

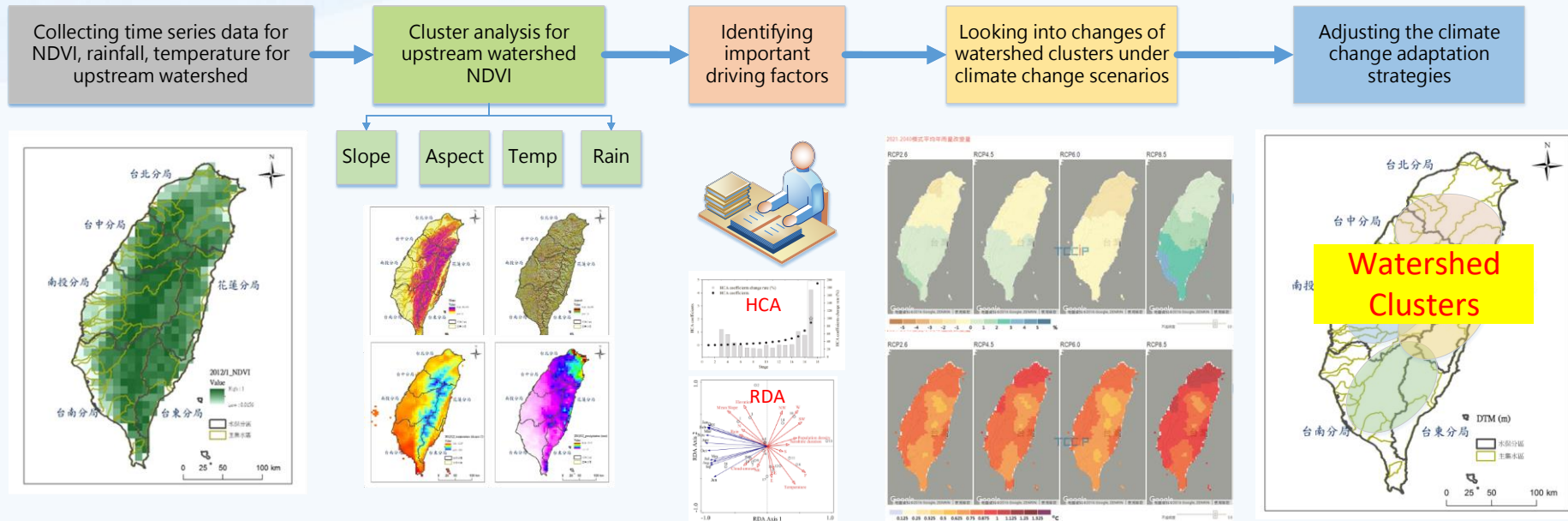
執行期間： 106年2月20日至106年12月31日
計畫主持人：蔡慧萍 助理教授
計畫編號： SWCB-106-048



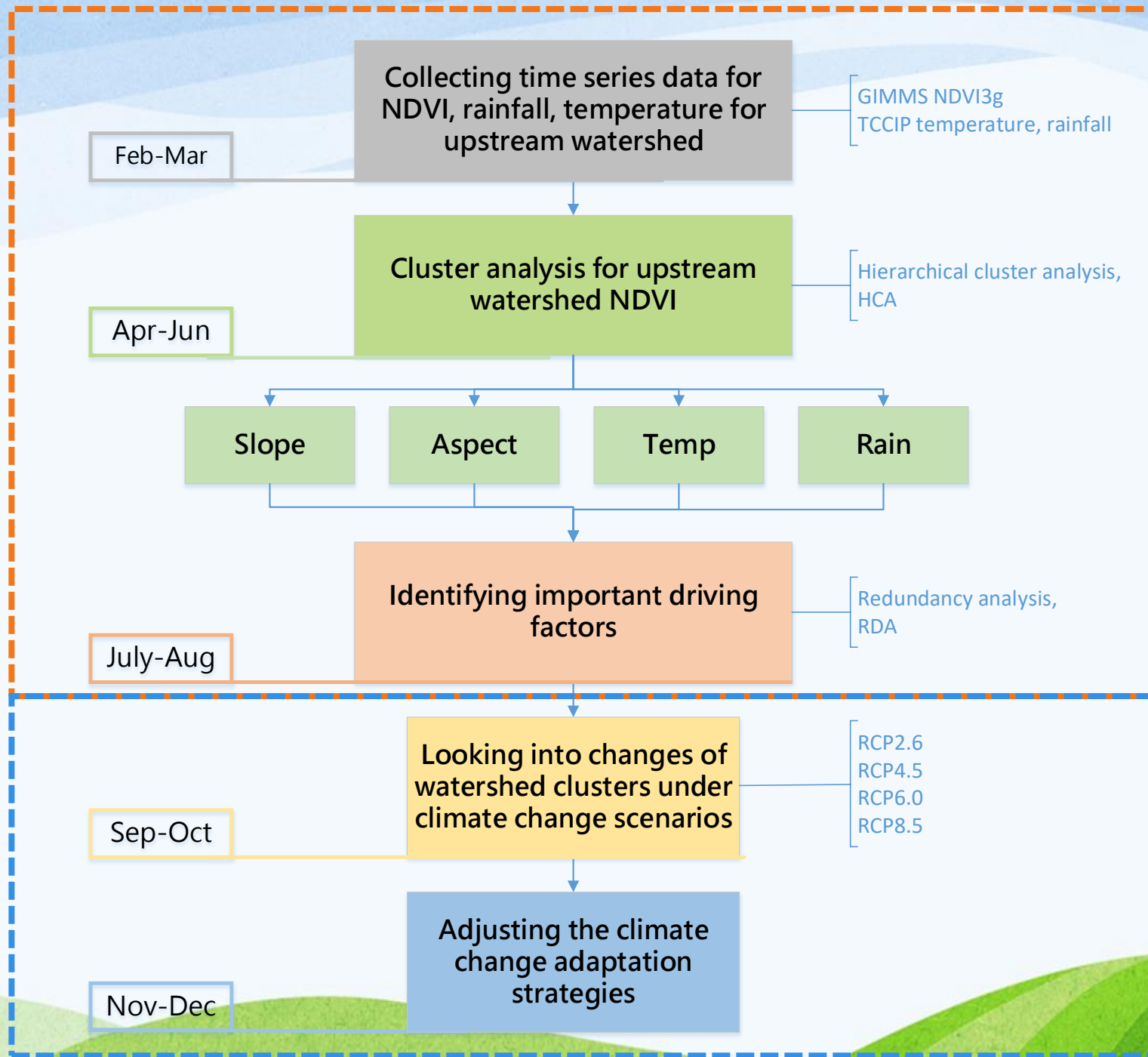
The story start with....



A proposed solution



Project goal	Problems to be solved	How?
Reduce the burden on the management agency by using watershed clusters as conservation management unit	1. Overall investigation of watersheds	Using 30 years remote sensed vegetation data
	2. Conservation management	Using watershed clusters as the conservation management unit
	3. Climate change adaptation strategy in upstream watershed	Incorporating with climate change scenarios



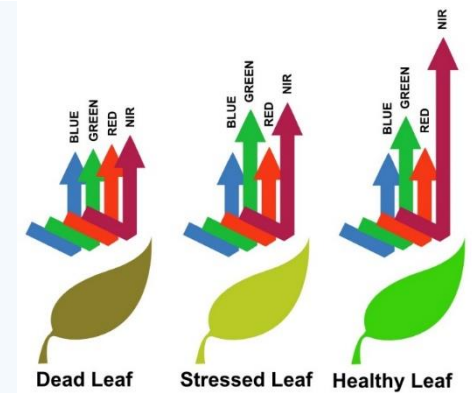
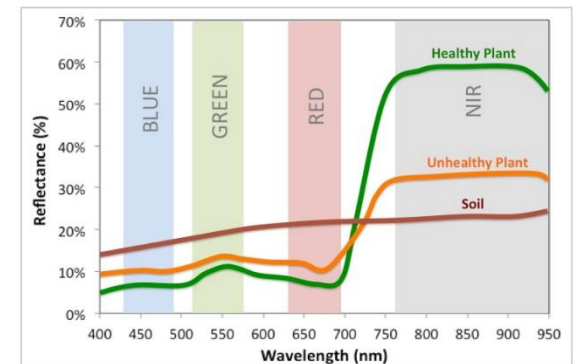
Materials

- 30 years monthly data (1982-2012)
 - The Normalized Difference Vegetation Index (NDVI) 常態化差異植生指標

$$NDVI = \frac{NIR - R}{NIR + R}$$

- Rainfall
- Temperature

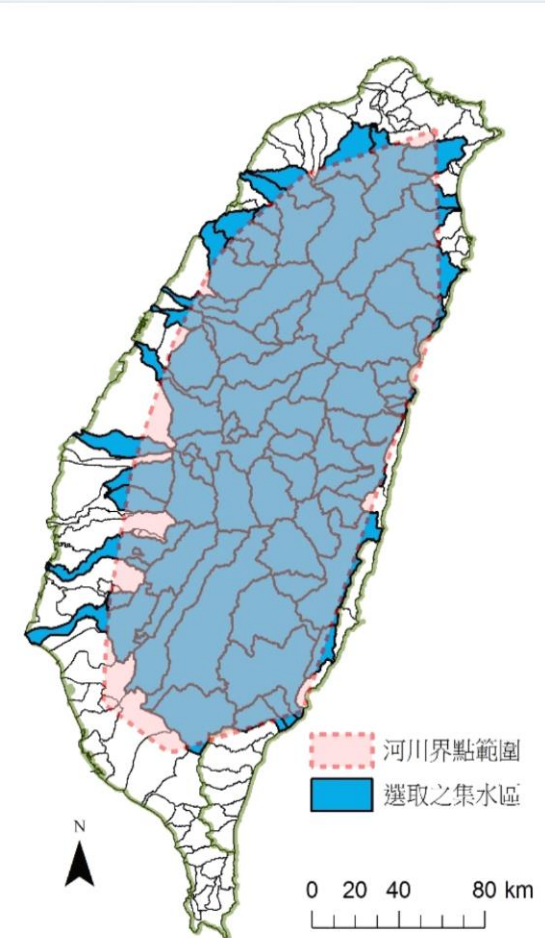
	NDVI	Climate data
Source	Global Land Cover Facility-Univ. Maryland	TCCIP
Dataset	The third generation of Global Inventory Modeling and Mapping Studies (GIMMS) Satellite Drift Corrected and NOAA-16 incorporated Normalized Difference Vegetation Index (NDVI)-NDVI3g	Precipitation Temperature
Temporal Coverage	Monthly maximum, 1982-2012	Monthly average, 1982-2012
Spatial Coverage	8 km * 8 km	5 km * 5 km



range: -1 ← → +1

Defining upstream watersheds

162 watersheds → River boundary point covered area → 70 watersheds were selected: watershed which has its central point fall within the river boundary point covered area

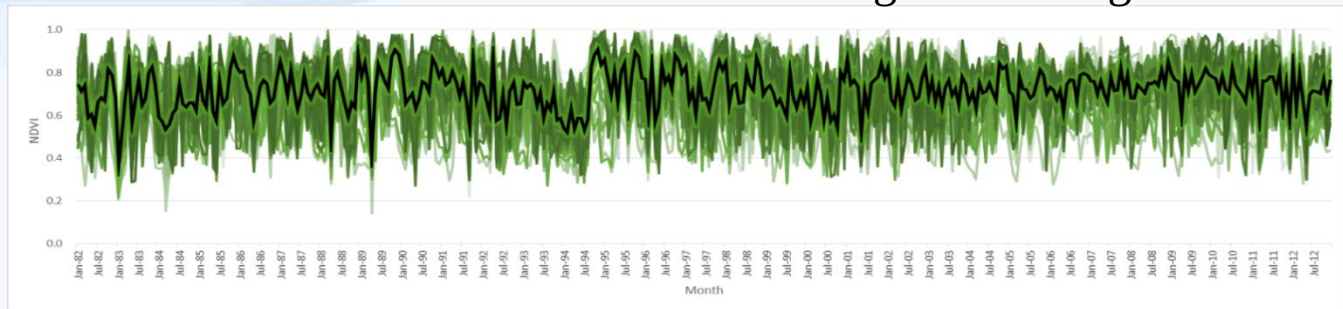


Collecting time series data for
NDVI, rainfall, temperature for
upstream watershed

GIMMS NDVI3g
TCCIP temperature, rainfall

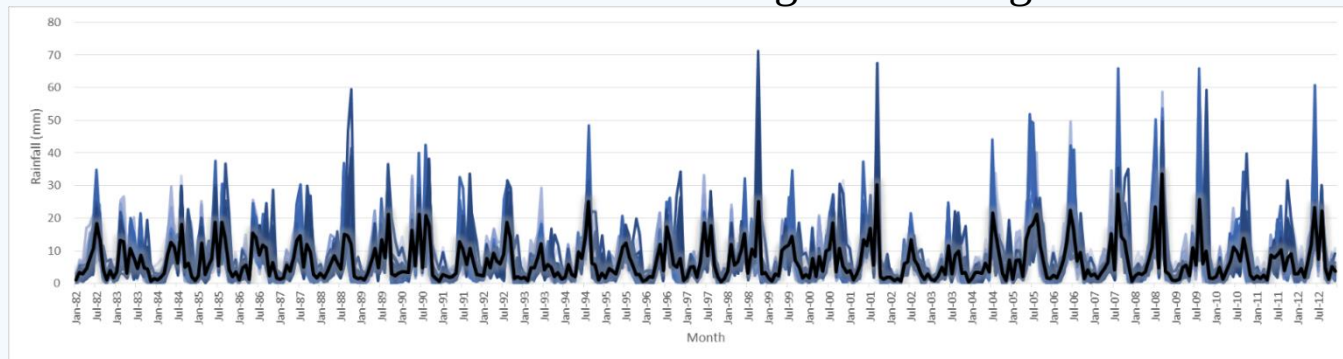
NDVI

Average value range:0.37-0.91



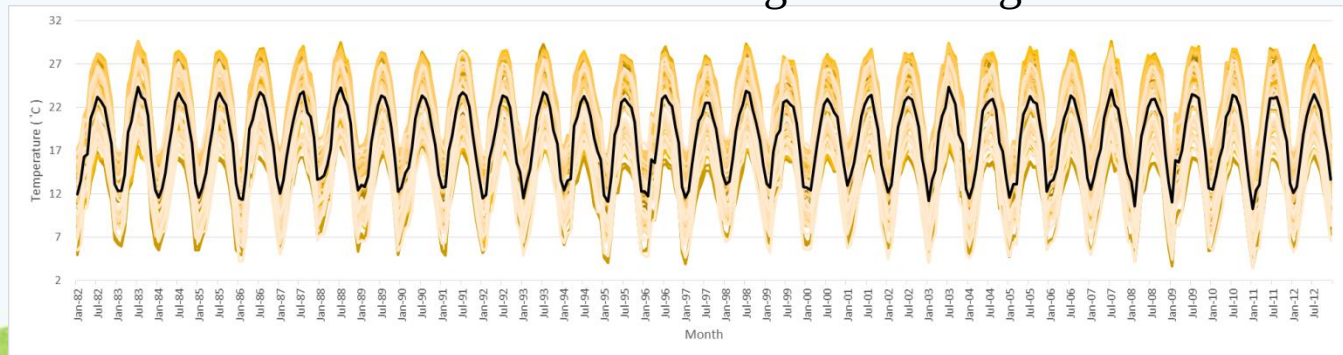
Rainfall

Average value range:0.37-33.49mm



Temperature

Average value range:10.27-24.36°C

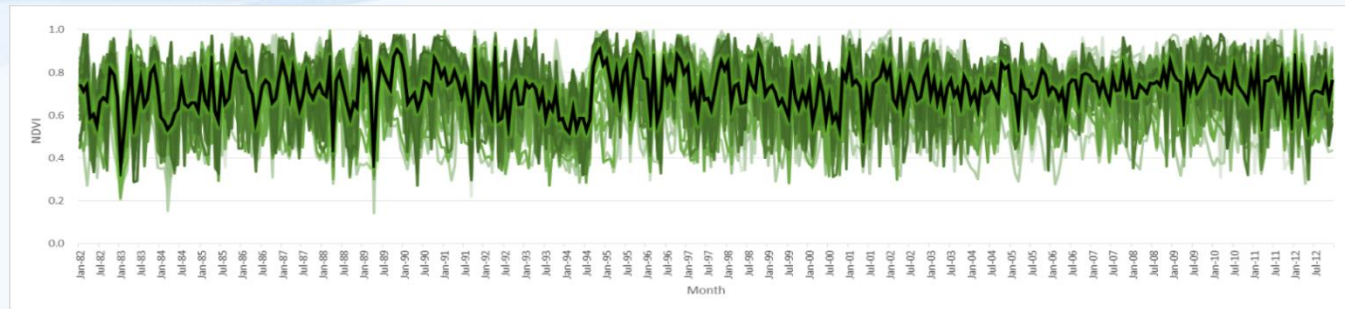


Collecting time series data for
NDVI, rainfall, temperature for
upstream watershed

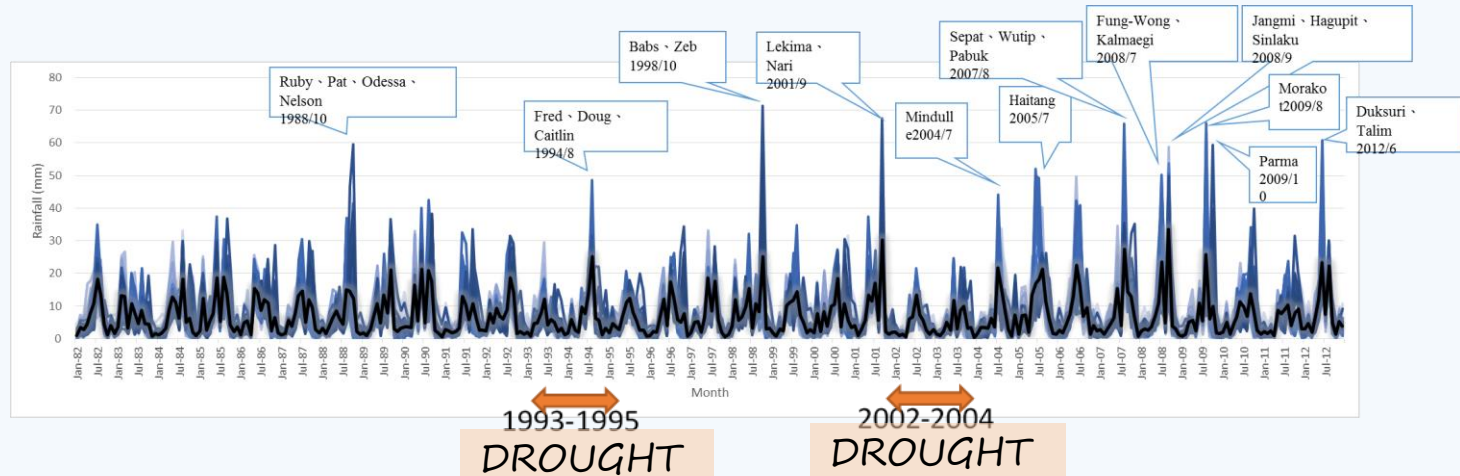
GIMMS NDVI3g
TCCIP temperature, rainfall

1993-1995

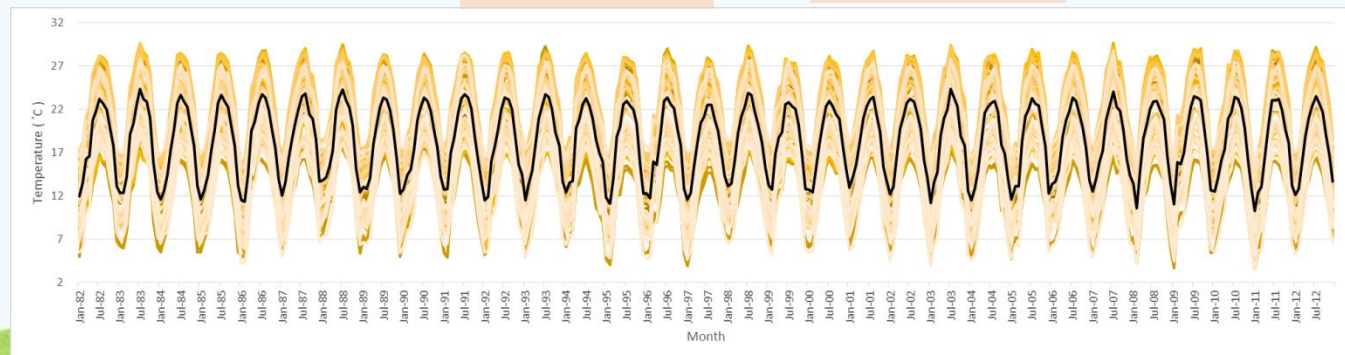
NDVI



Rainfall



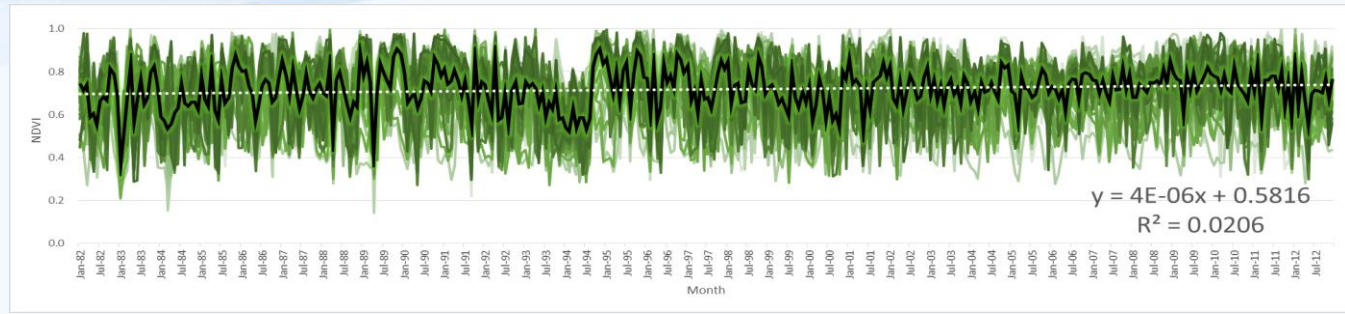
Temperature



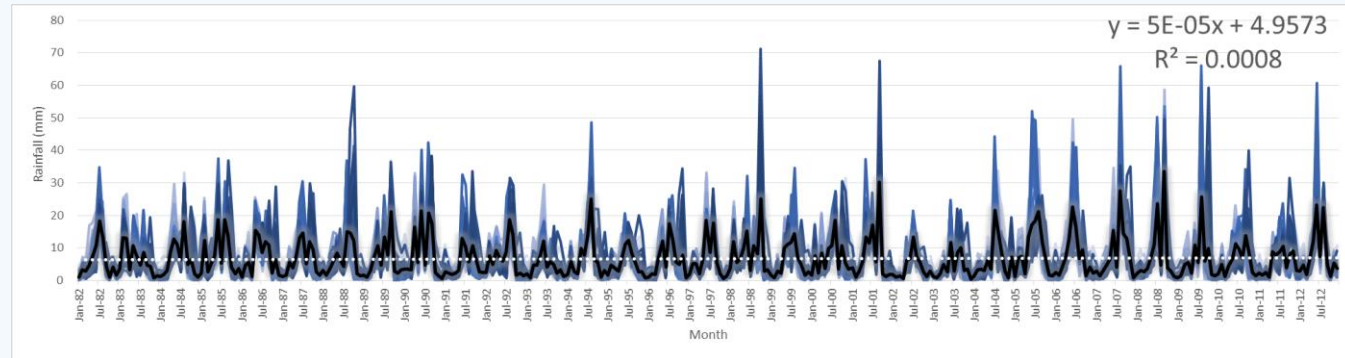
Collecting time series data for NDVI, rainfall, temperature for upstream watershed

GIMMS NDVI3g
TCCIP temperature, rainfall

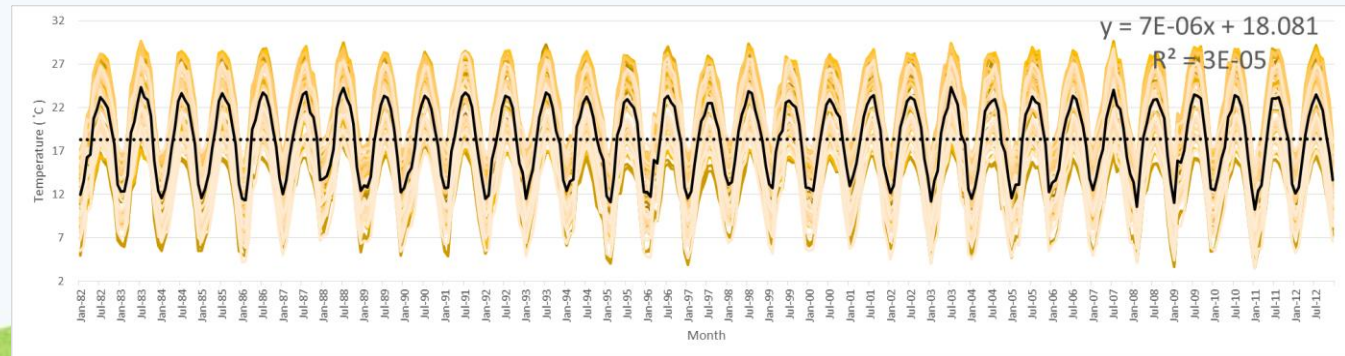
NDVI



Rainfall

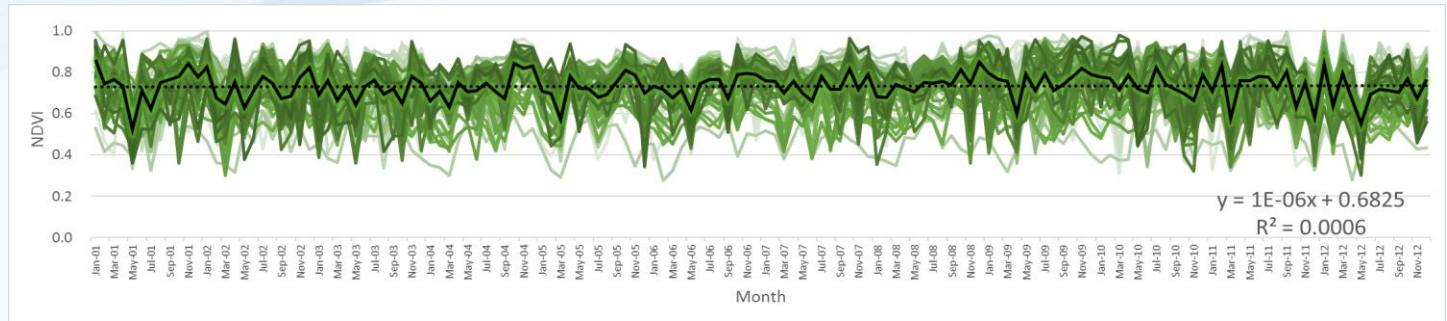


Temperature



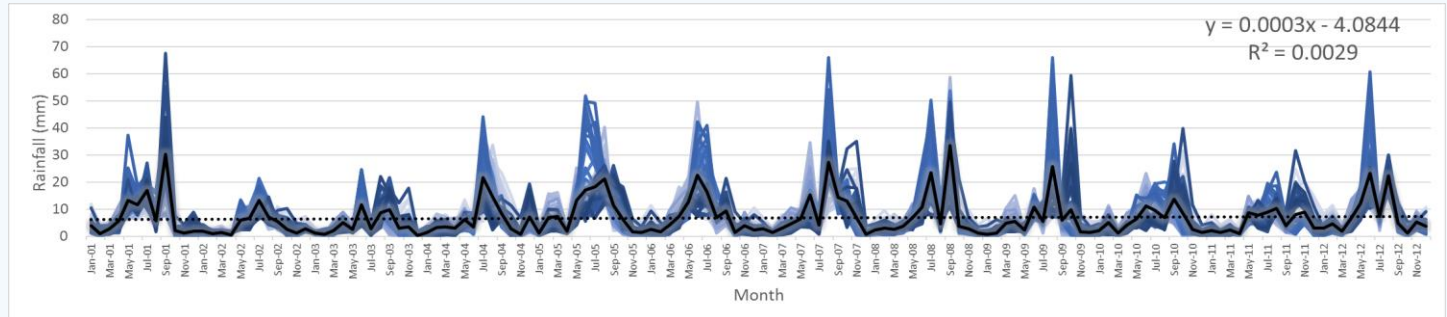
2001-2012 time series data

NDVI



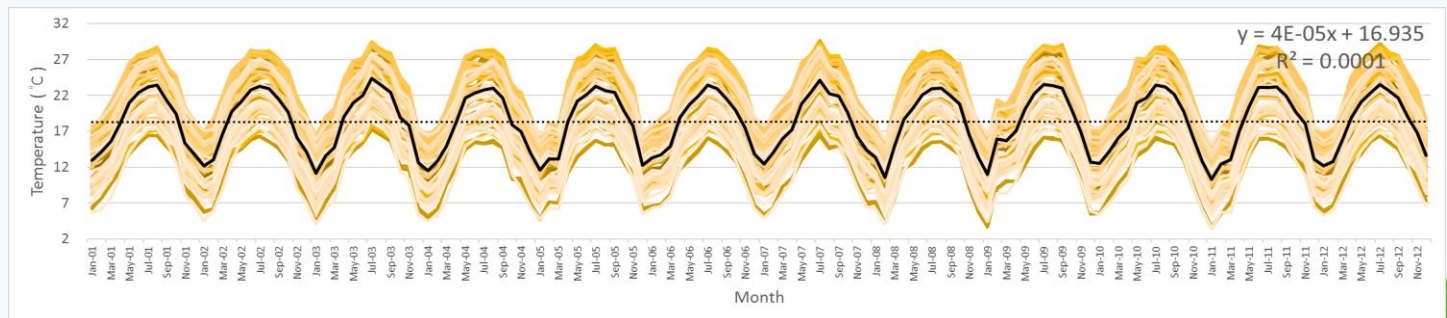
(a)

Rainfall



(b)

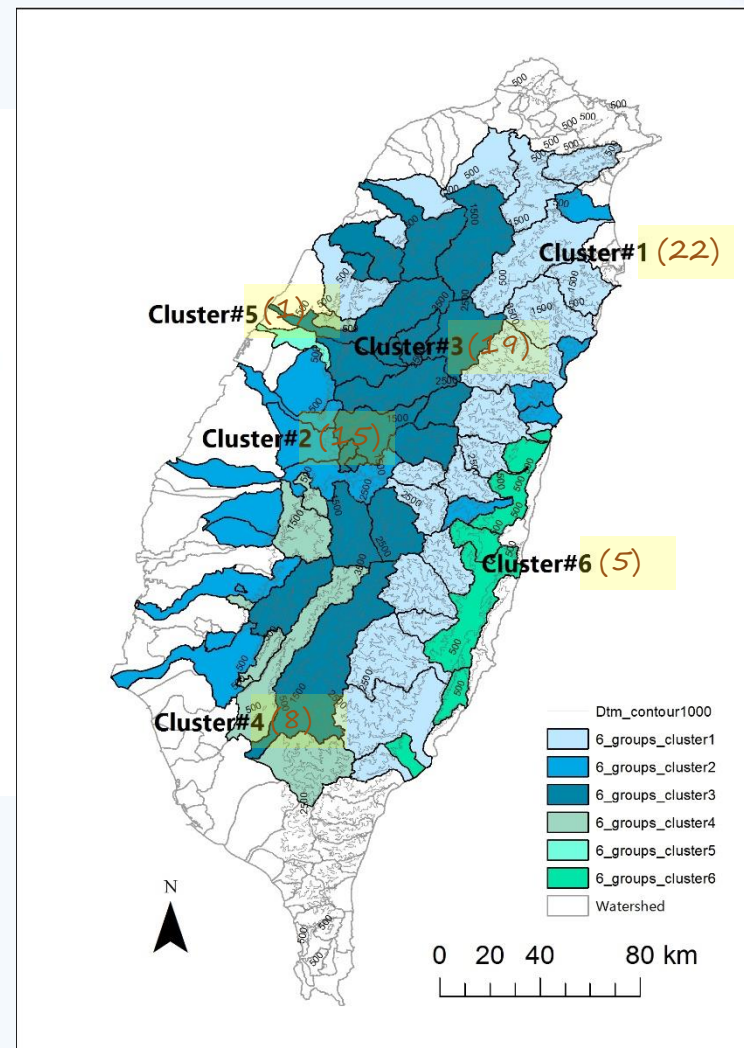
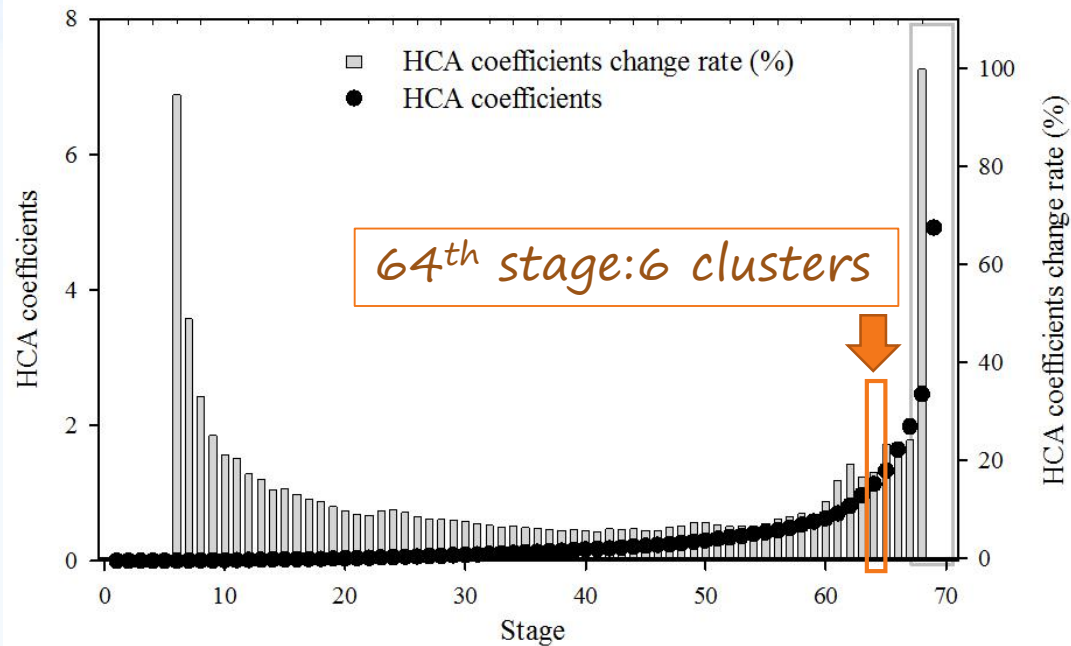
Temperature



(c)

Cluster analysis for upstream watershed NDVI

Hierarchical cluster analysis,
HCA



Identifying important driving factors

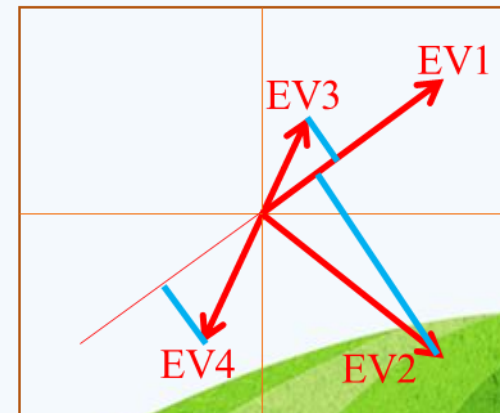
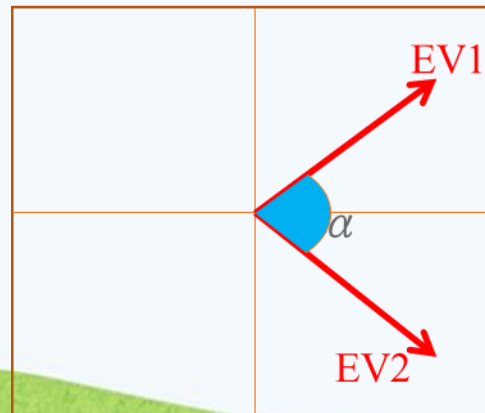
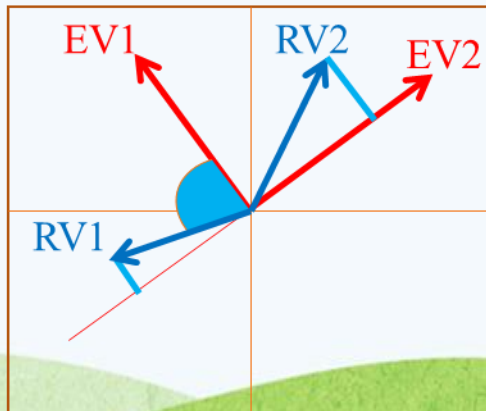
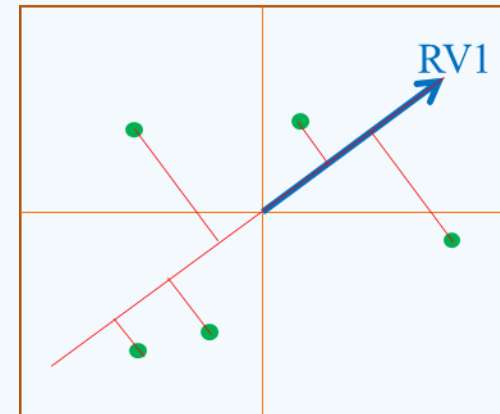
Redundancy analysis,
RDA

Cases : 70 watersheds

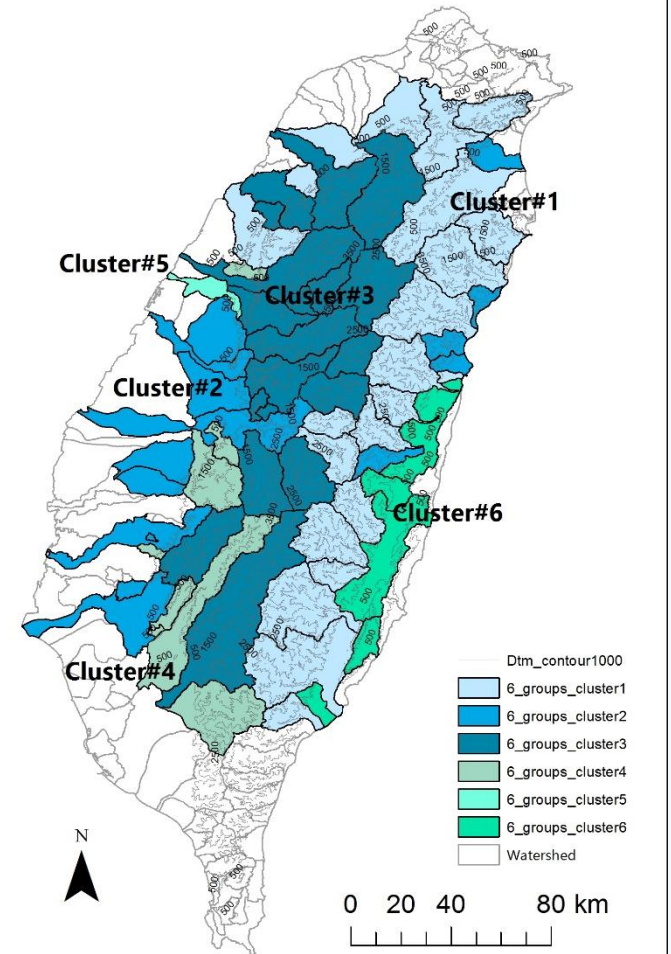
Response variable (RV): NDVI

Explanatory variable (EV): Rainfall, Temperature, Slope, Aspect

Compared entities	Scaling with focus on RV correlations
RVs vs cases	(Fitted) RV values in cases
Cases vs cases	n.a.
RVs vs RVs	Linear correlations (covariances) among RVs
RVs vs EVs	Linear correlations between RVs and EVs
Cases vs EVs	Values of EVs
EVs vs EVs	Correlations among EVs
Biplot with this scaling is called	Correlation biplot
RV arrows length shows	Approximate std. deviation of RV values

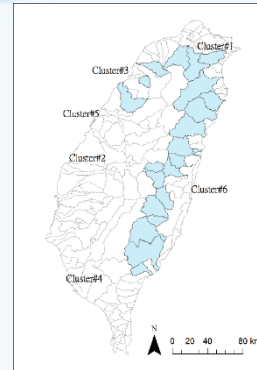
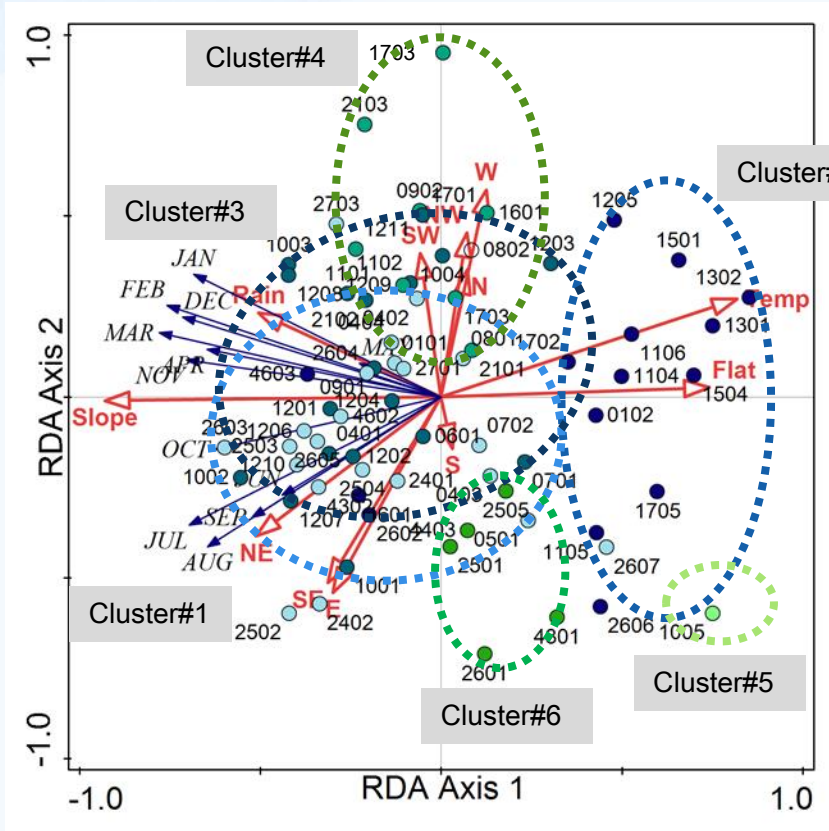


Hierarchical cluster analysis, HCA

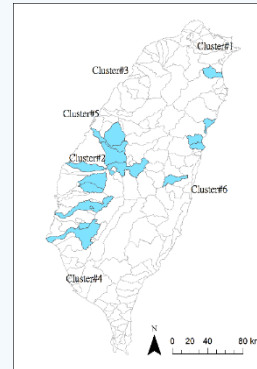


Cluster analysis for upstream watershed NDVI

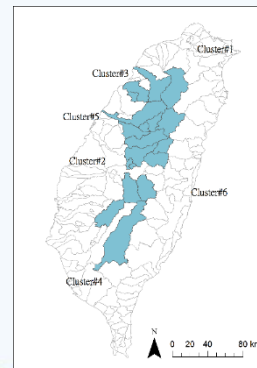
Hierarchical cluster analysis,
HCA



- Cluster#1
 - Higher NDVI
 - Higher rain
 - Higher slope
 - Lower temp
 - E, NE, SE

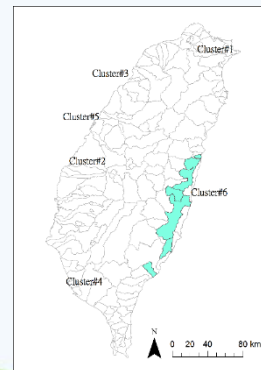


- Cluster#2
 - Lower NDVI
 - Lower rain
 - Lower slope
 - Higher temp
 - Flat

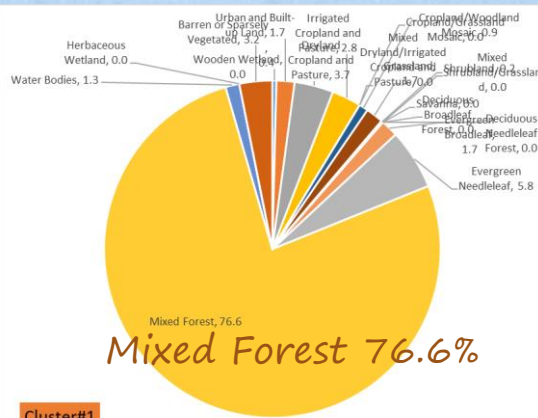


- Cluster#3
 - Higher NDVI
 - Higher rain
 - Higher slope
 - Lower temp
 - W, N

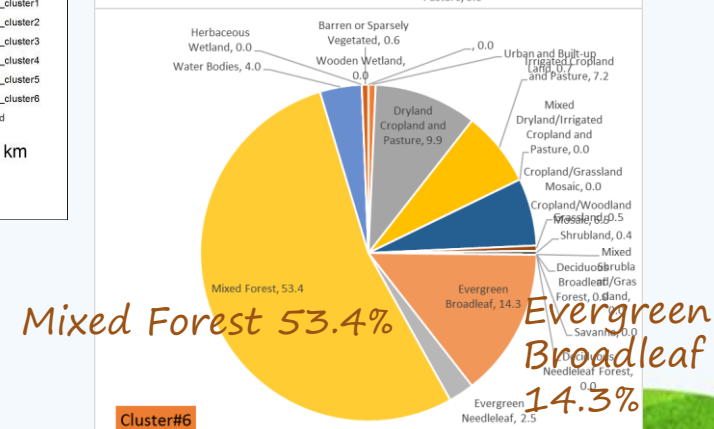
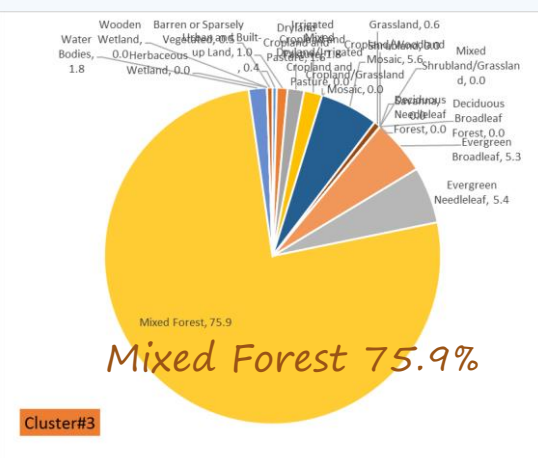
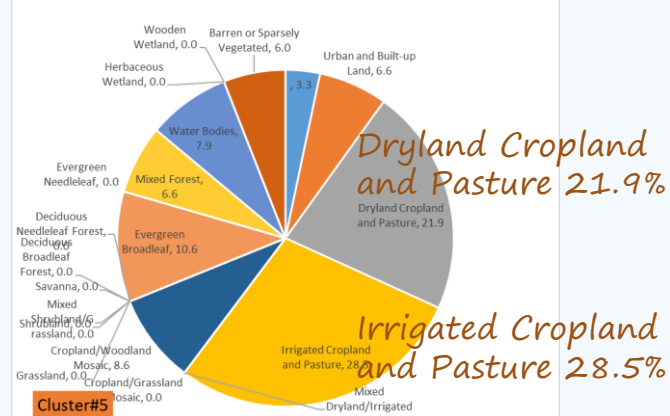
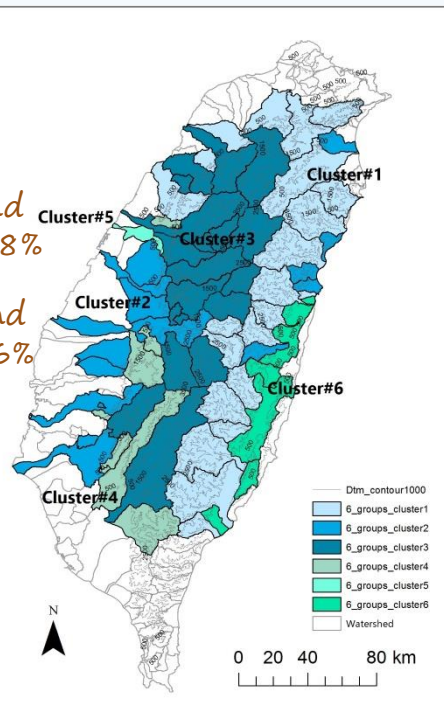
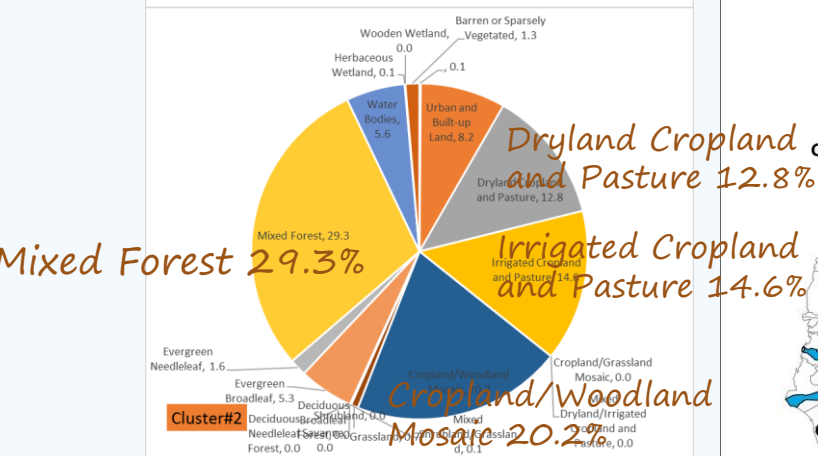
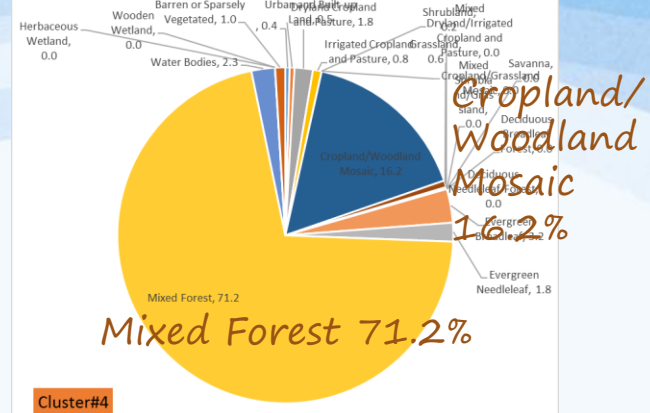
Hierarchical cluster analysis, HCA



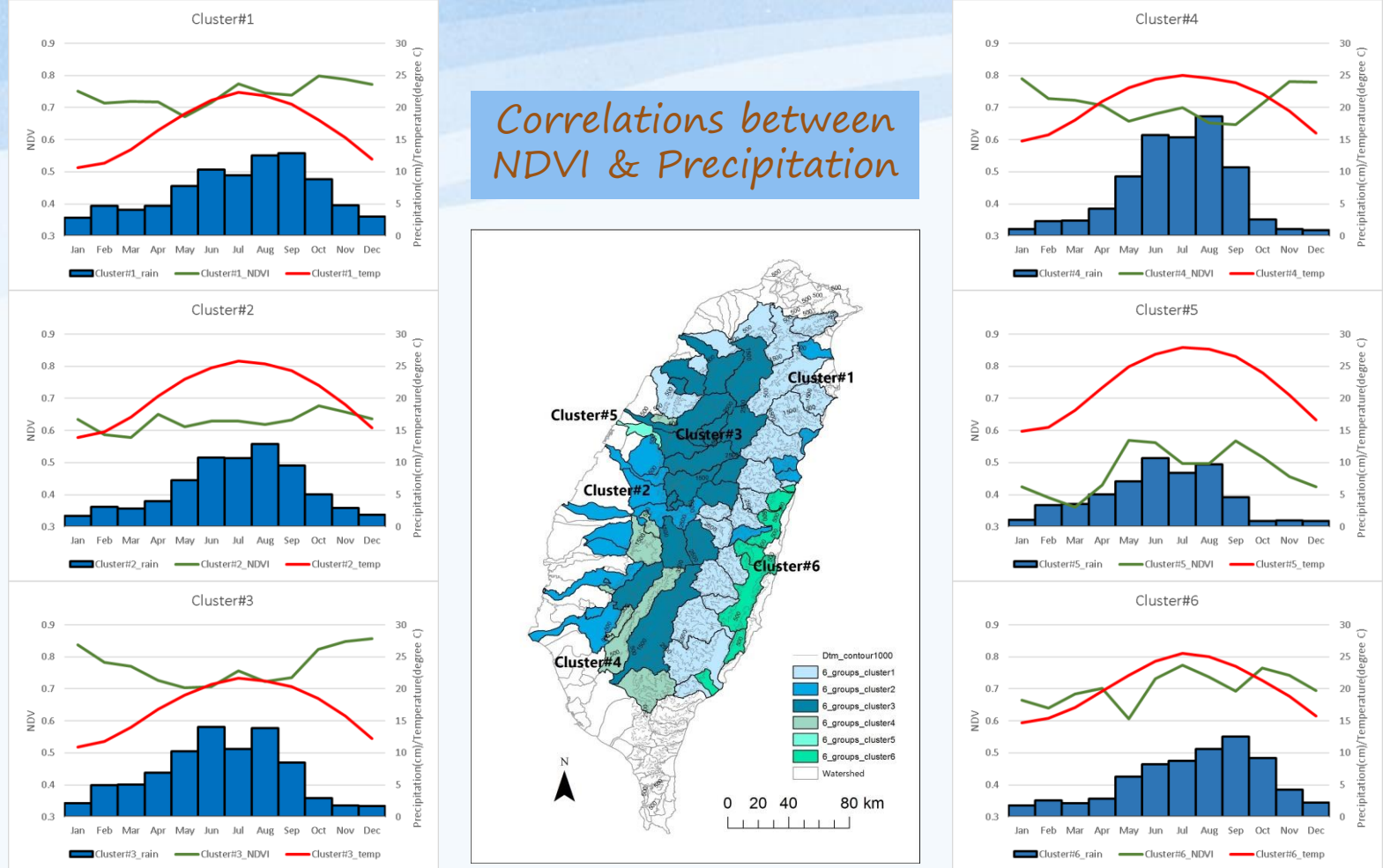
- Cluster#4
 - Medium NDVI
 - Medium rain
 - Medium slope
 - Medium temp
 - W, N
- Cluster#5
 - Low NDVI
 - Lower rain
 - Lower slope
 - Higher temp
 - Flat
- Cluster#6
 - Medium NDVI
 - Medium rain
 - Medium slope
 - Medium temp
 - SE, E



Land cover classes
% for each cluster



Correlations between NDVI & Precipitation



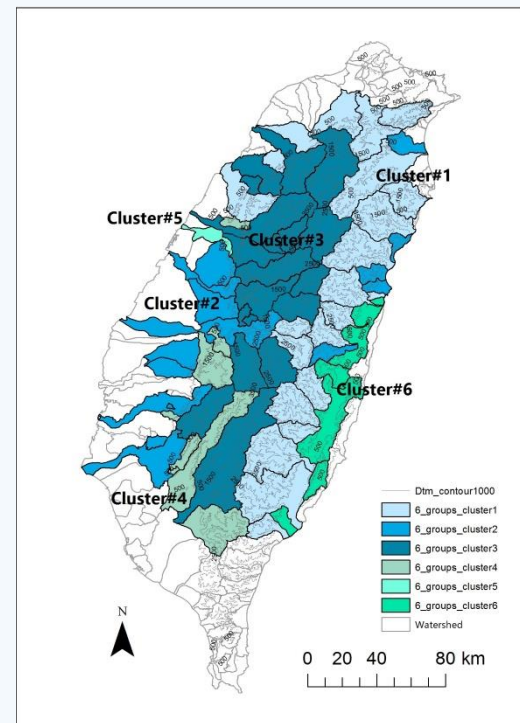
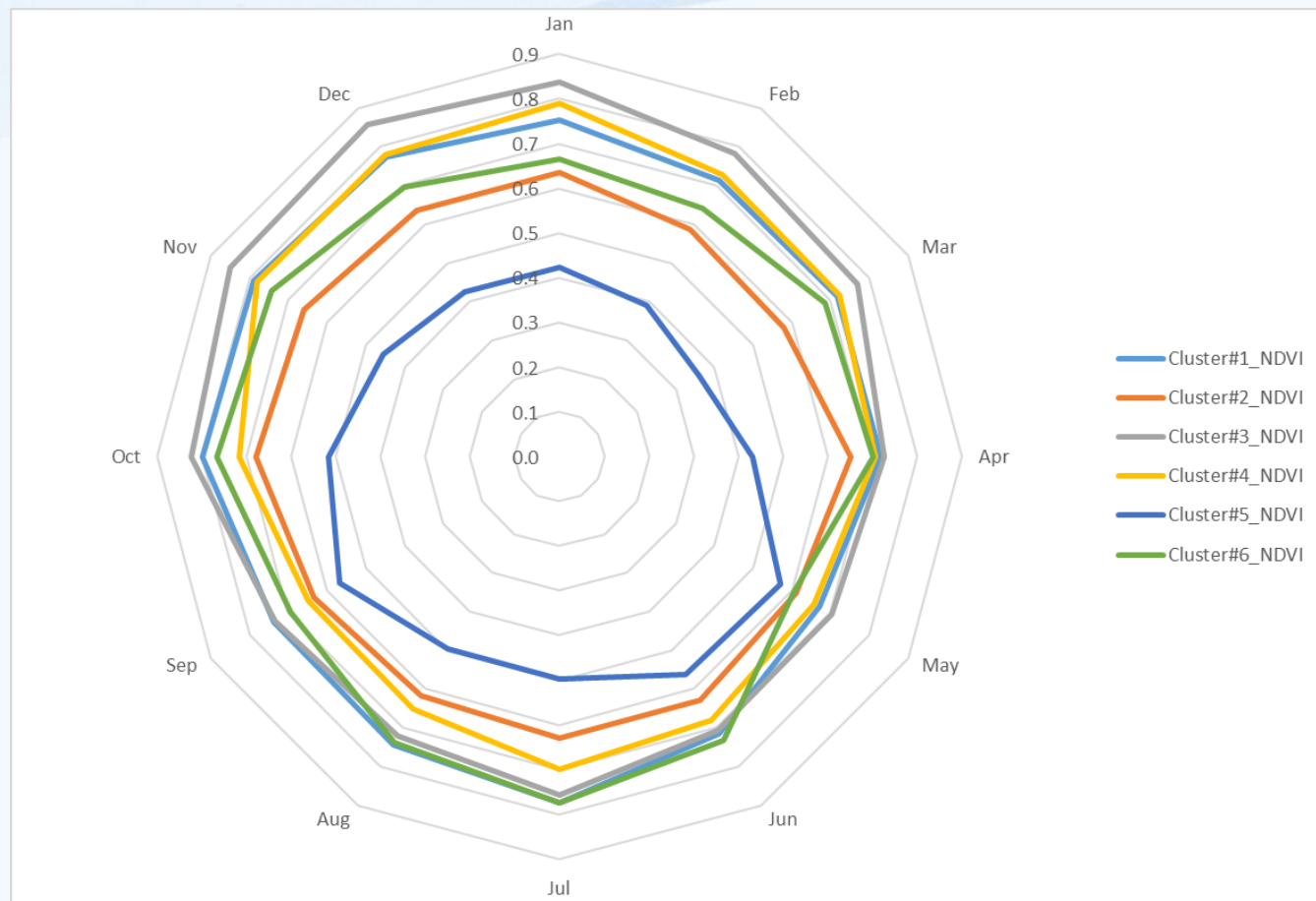
Correlations between NDVI and precipitation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
r	.126	.315**	.301*	.282*	.305*	-.036	-.188	-.292*	.108	.135	-.023	.034

** . Correlation is significant at the 0.01 level (2-tailed)

* . Correlation is significant at the 0.05 level (2-tailed)

NDVI for each cluster

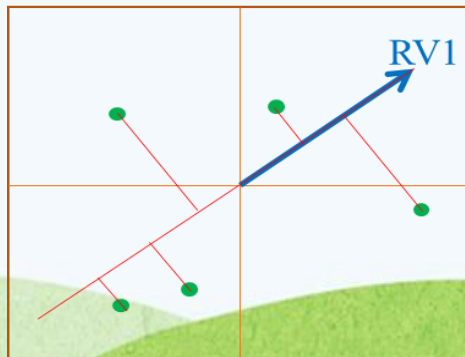
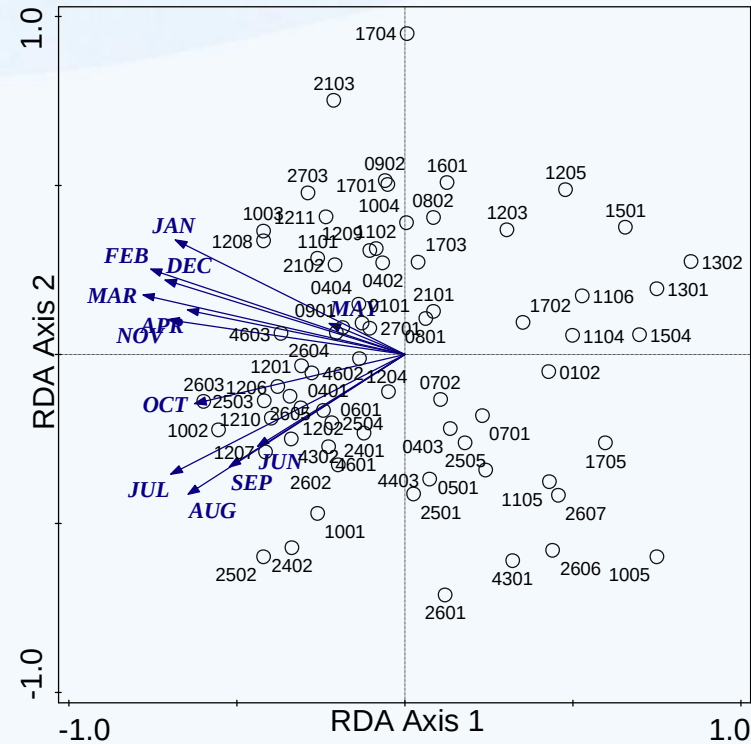


Cluster #3 > #4 > #1 > #6 > #2 > #5

Identifying important driving factors

Redundancy analysis,
RDA

Rainfall, Temperature, Slope, Aspect

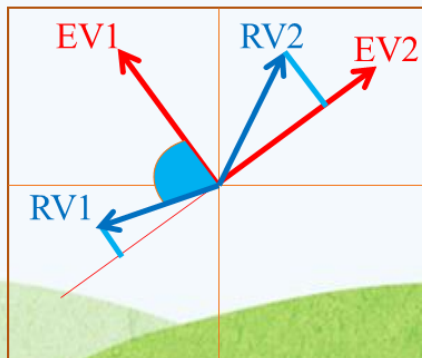
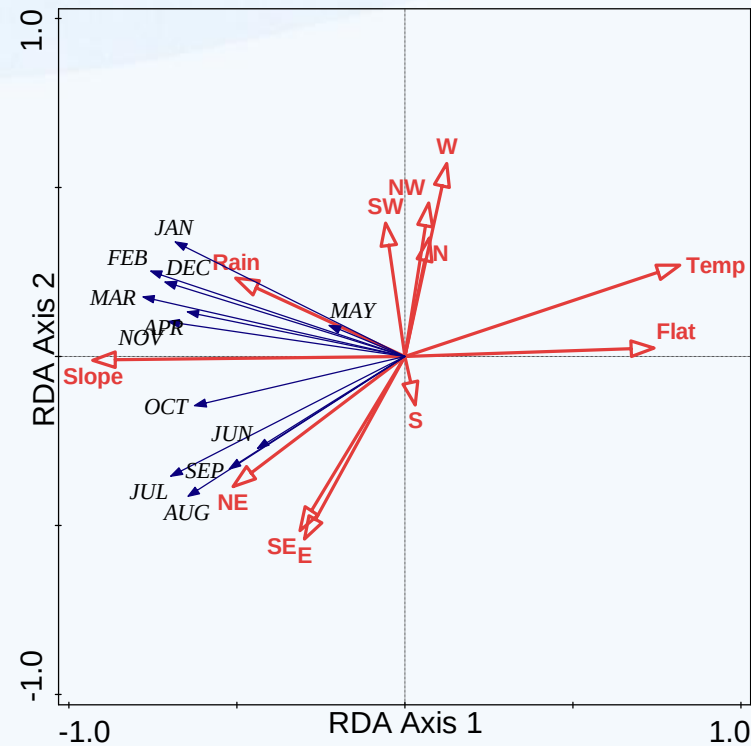


NDVI	Axis 1 (%)	Axis 1 and 2 (%)	Total (%)
JAN	46.72	58.22	58.52
FEB	57.39	63.80	64.51
MAR	60.83	63.97	66.20
APR	42.00	43.74	47.60
MAY	5.10	5.96	35.22
JUN	19.31	26.68	33.46
JUL	48.56	61.10	63.76
AUG	41.80	58.96	60.19
SEP	27.30	38.39	45.12
OCT	39.20	41.31	46.42
NOV	49.65	50.72	52.08
DEC	51.05	55.93	56.70
Average	40.74	47.40	52.48

Identifying important driving factors

Redundancy analysis,
RDA

Rainfall, Temperature, Slope, Aspect

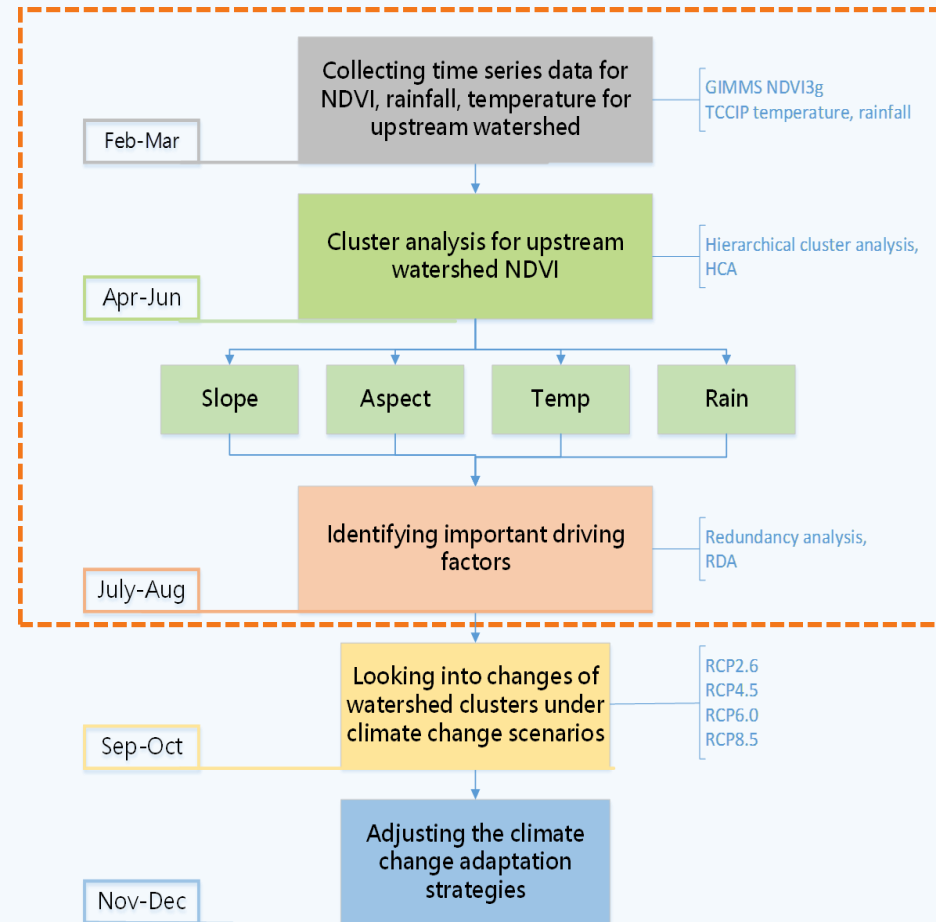


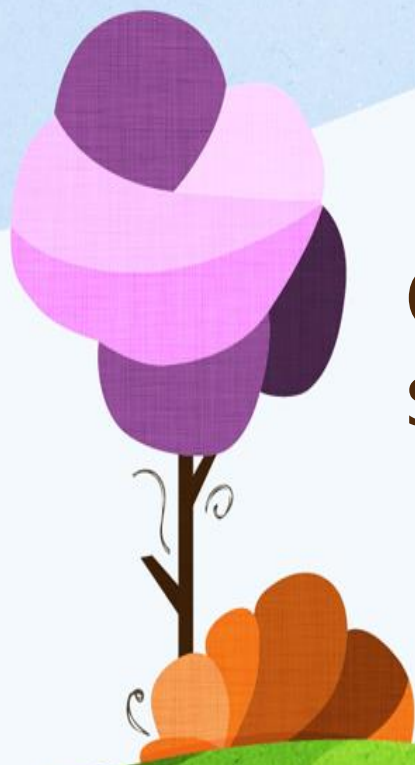
Name of variable	Explains %
Slope	35.2****
Temp	27.8****
Flat	17.2****
NE	11.2****
Rain	10.6****
E	5.9**
SE	5.7**
W	5.2**
NW	3.6*
SW	2.7
N	2.5
S	0.3

**** $p < 0.001$; *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

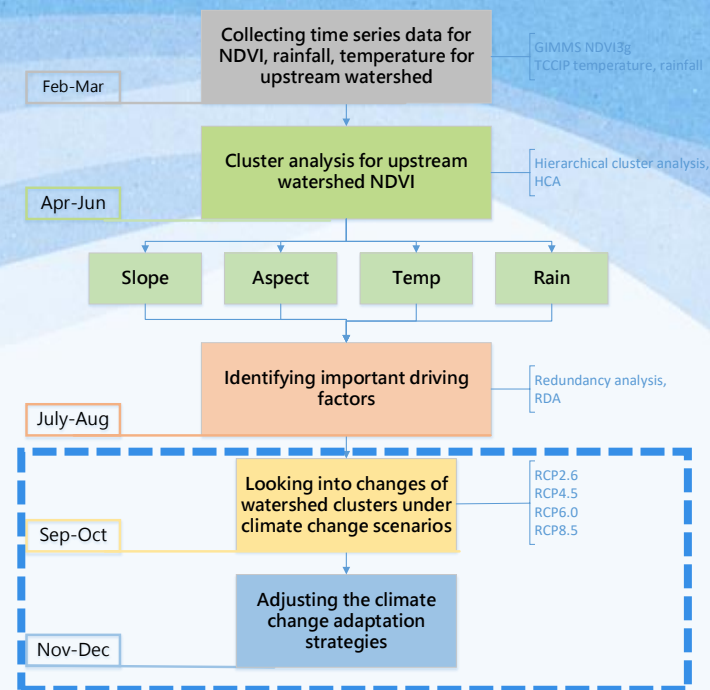
Mid-Term Summary

- Time series data of NDVI, rainfall, temperature were collected
- Cluster analysis results:
 - 6 clusters
- Important driving factors (0.001 sig. level):
 - Slope
 - Temperature
 - Aspects: flat
 - NE facing slope
 - Rainfall





Climate change scenarios for each cluster



Model: HadGEM2-AO
Scenarios:

RCP 2.6: 暖化減緩

RCP 4.5: 暖化穩定

RCP 6.0: 暖化穩定

RCP 8.5: 溫室氣體高度排放

Temporal coverage (4 seasons)

2021-2040

2041-2060

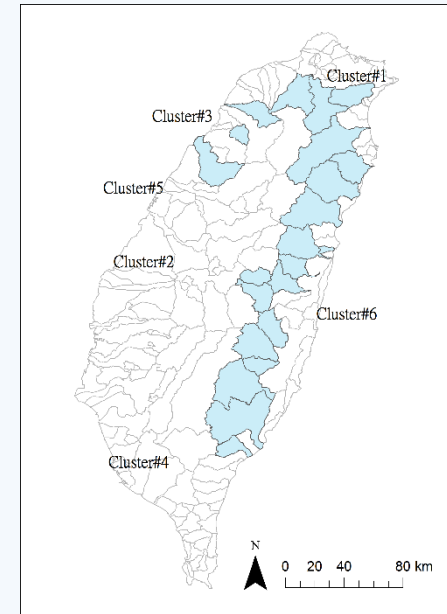
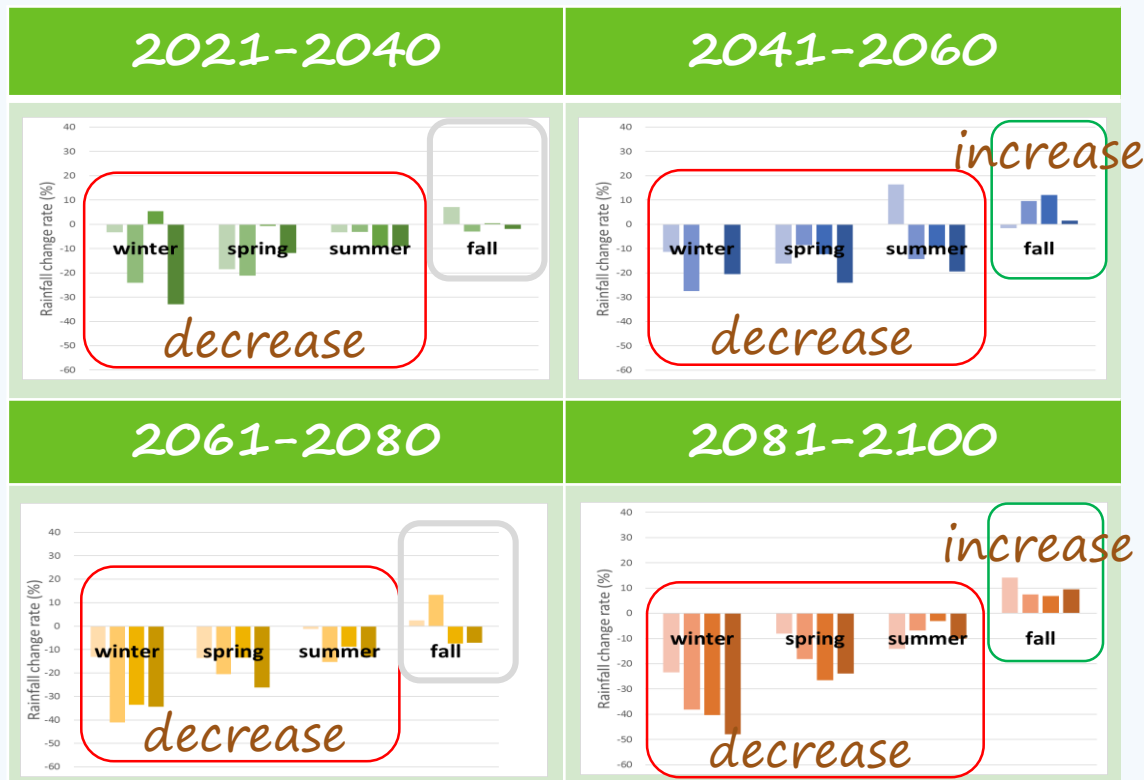
2061-2080

2081-2100

Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

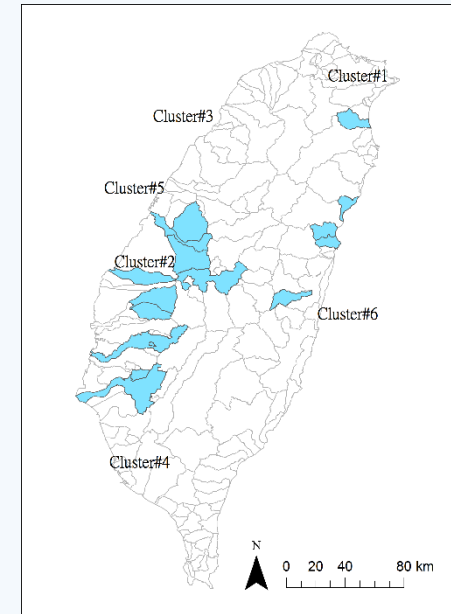
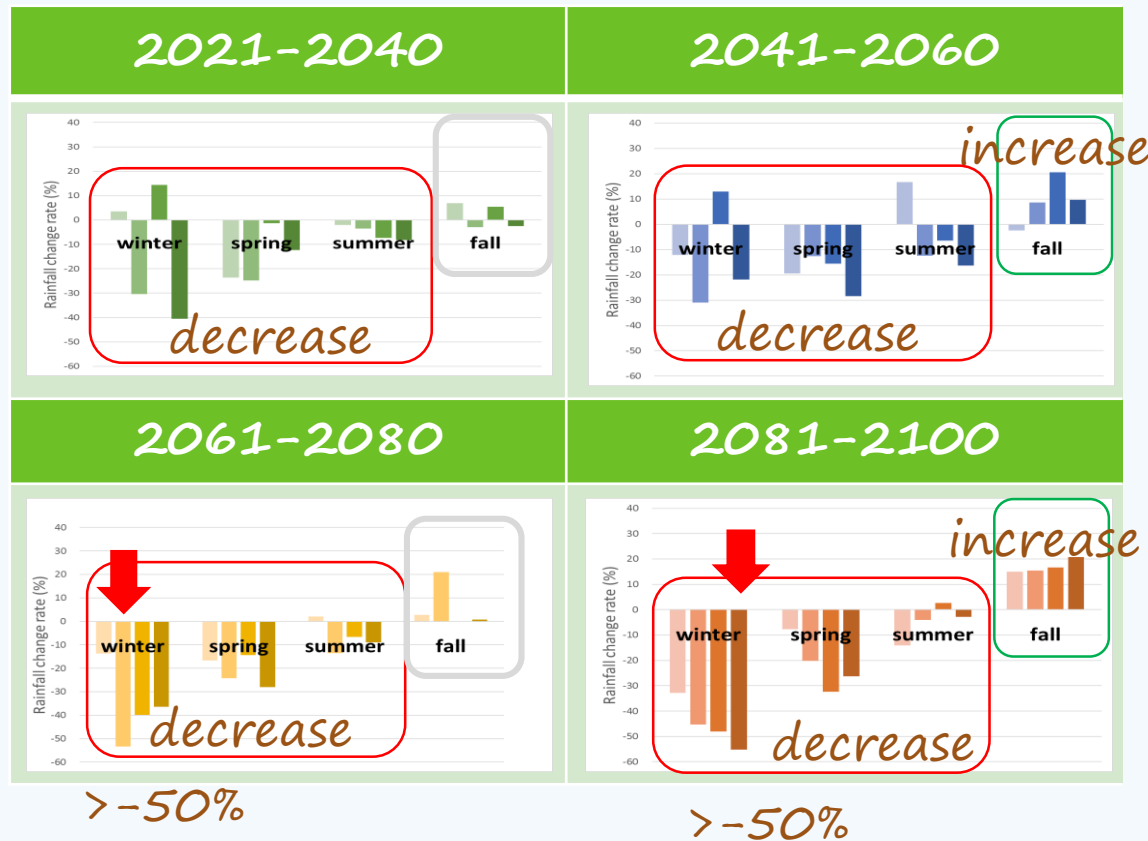
Rain change rate - Cluster 1



Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

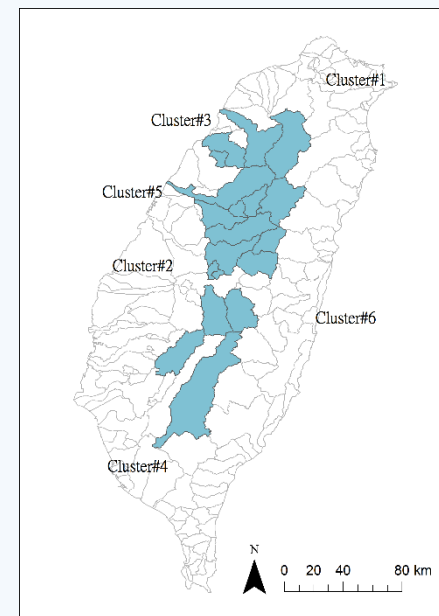
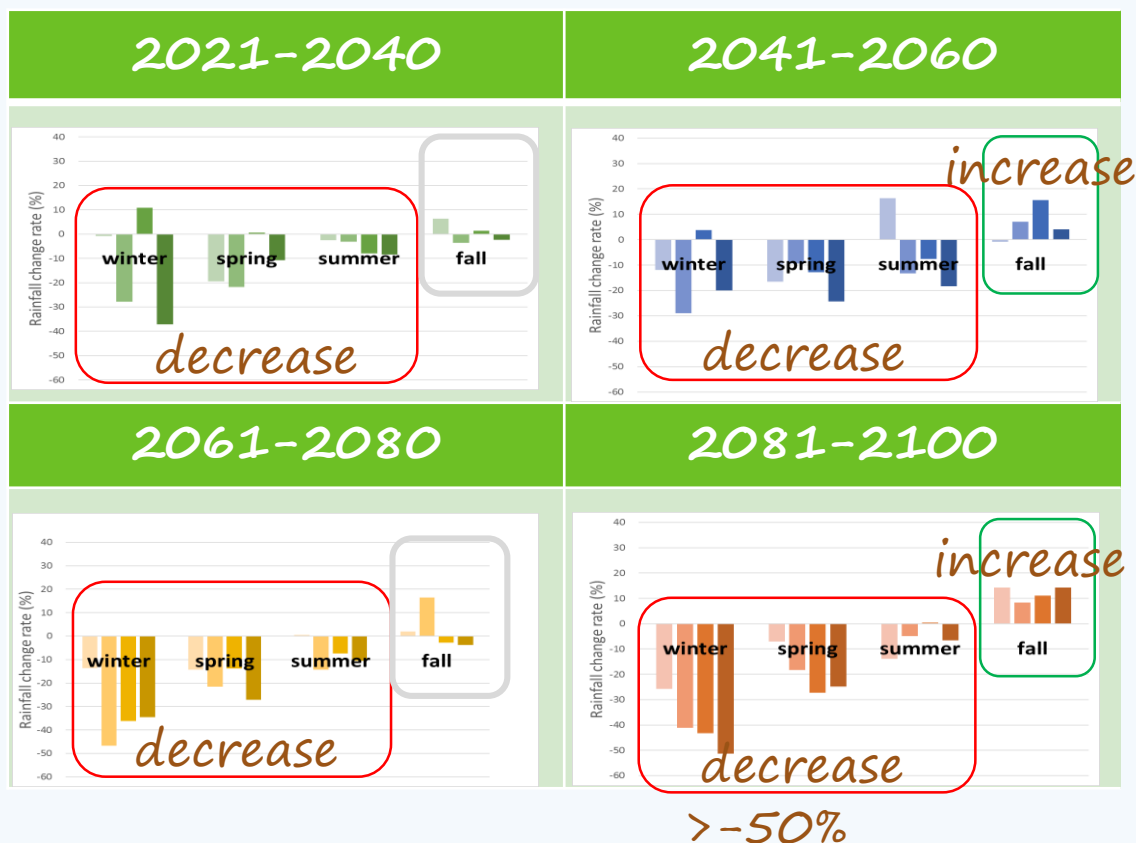
Rain change rate - Cluster 2



Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

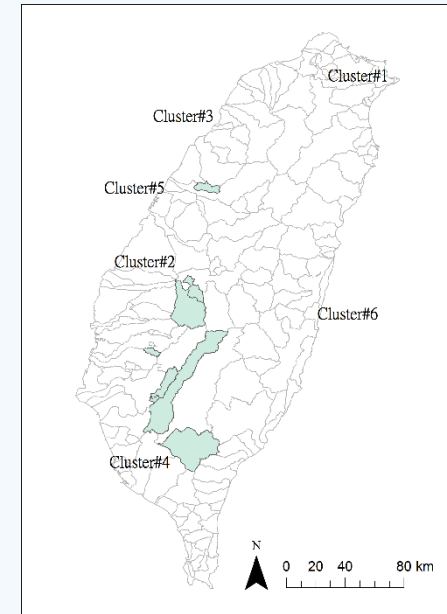
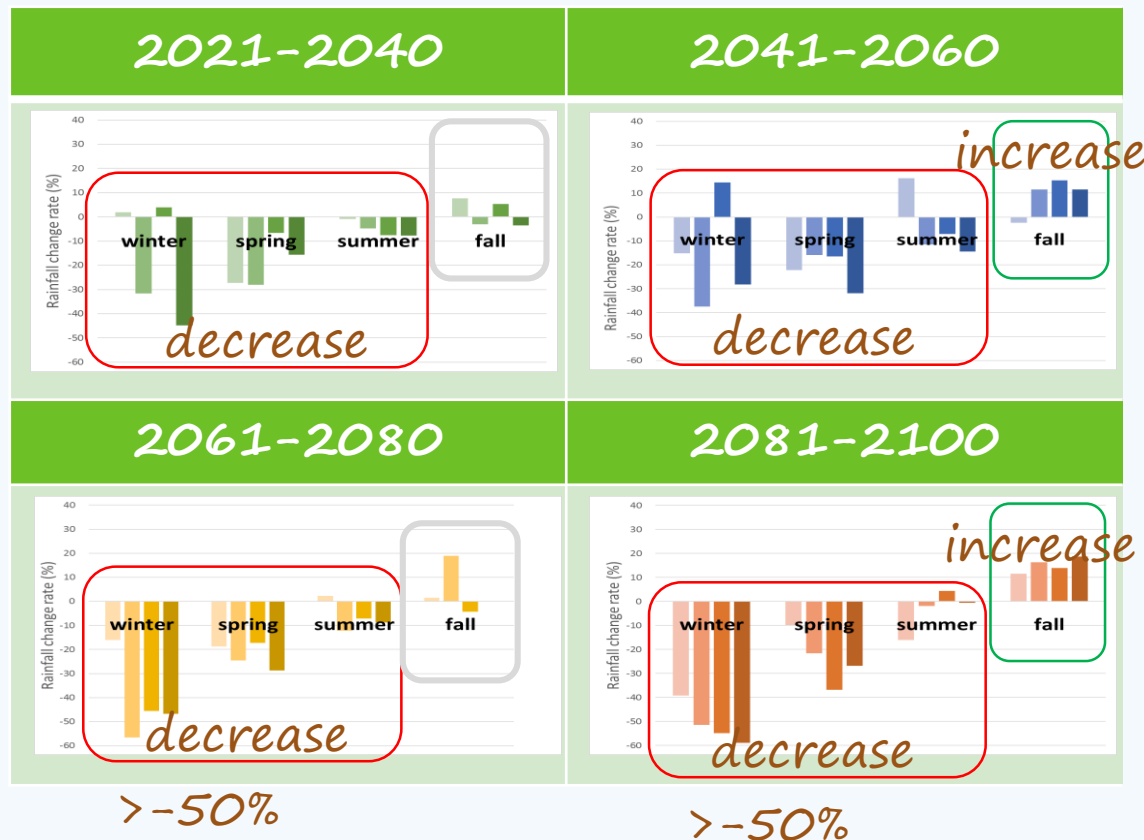
Rain change rate - Cluster 3



Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

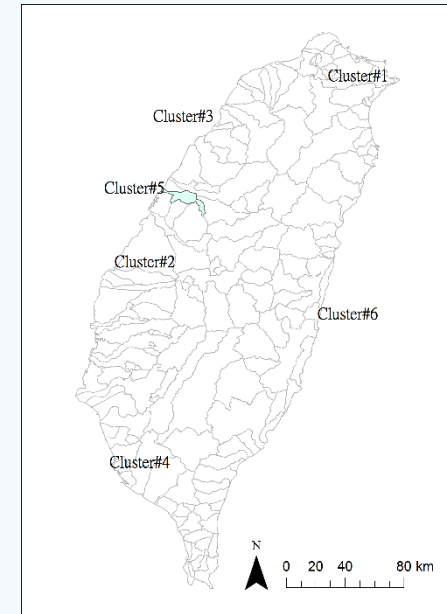
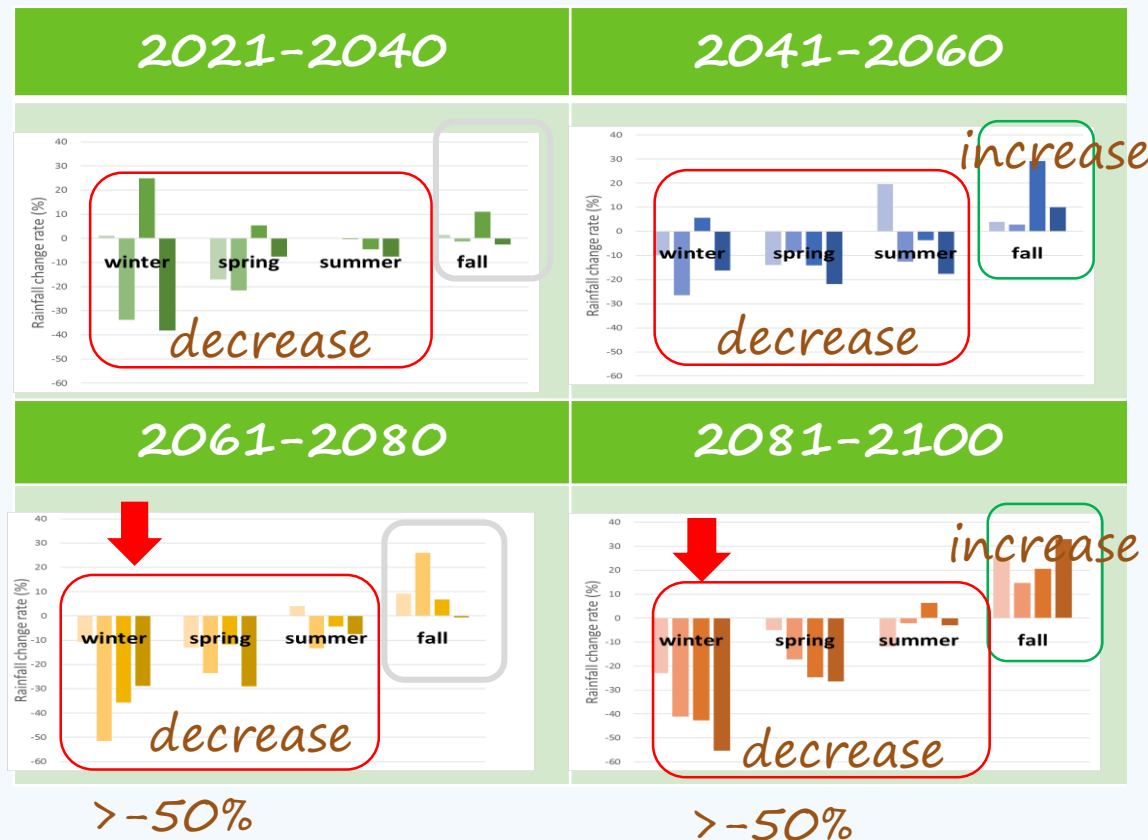
Rain change rate - Cluster 4



Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

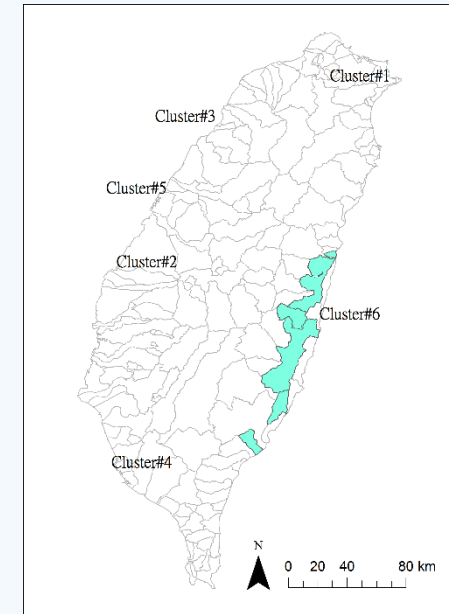
Rain change rate - Cluster 5



Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

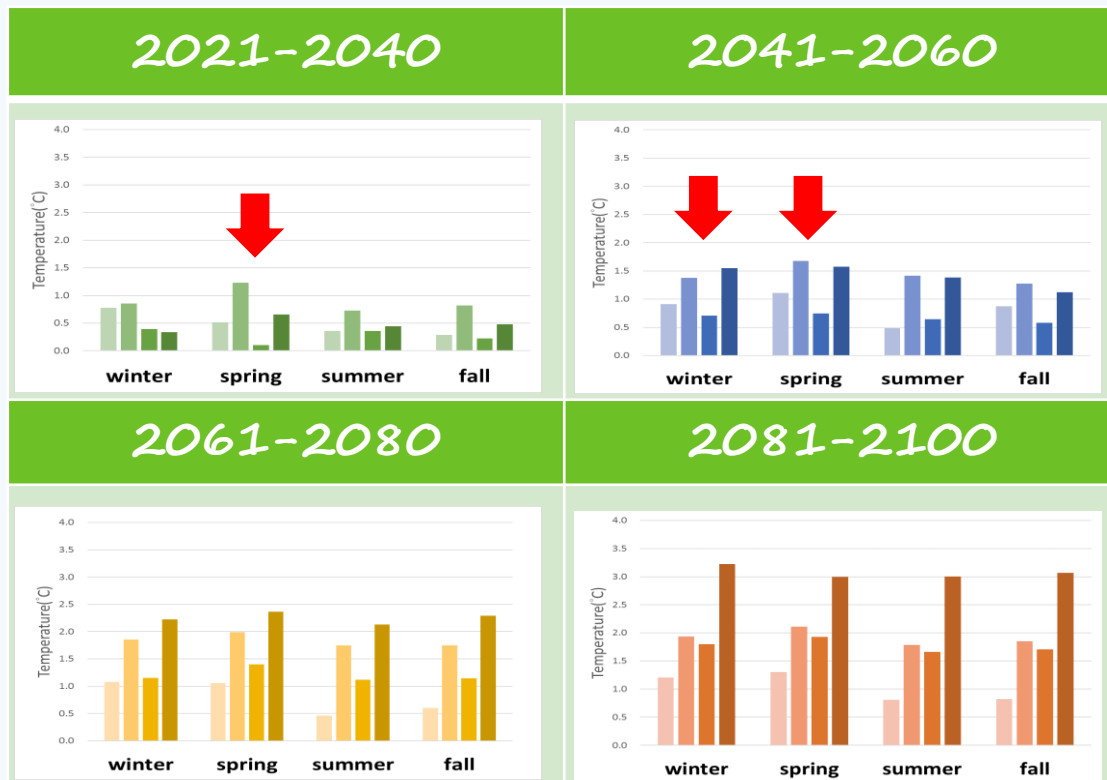
Rain change rate - Cluster 6



Looking into changes of watershed clusters under climate change scenarios

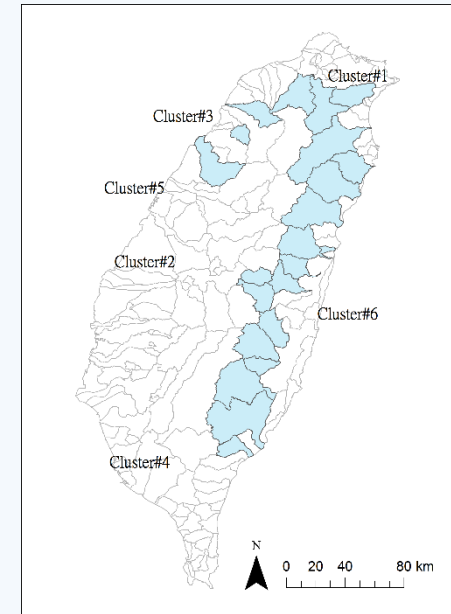
RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temperature - Cluster 1



Increase > 2°C

Increase > 3°C



Legend

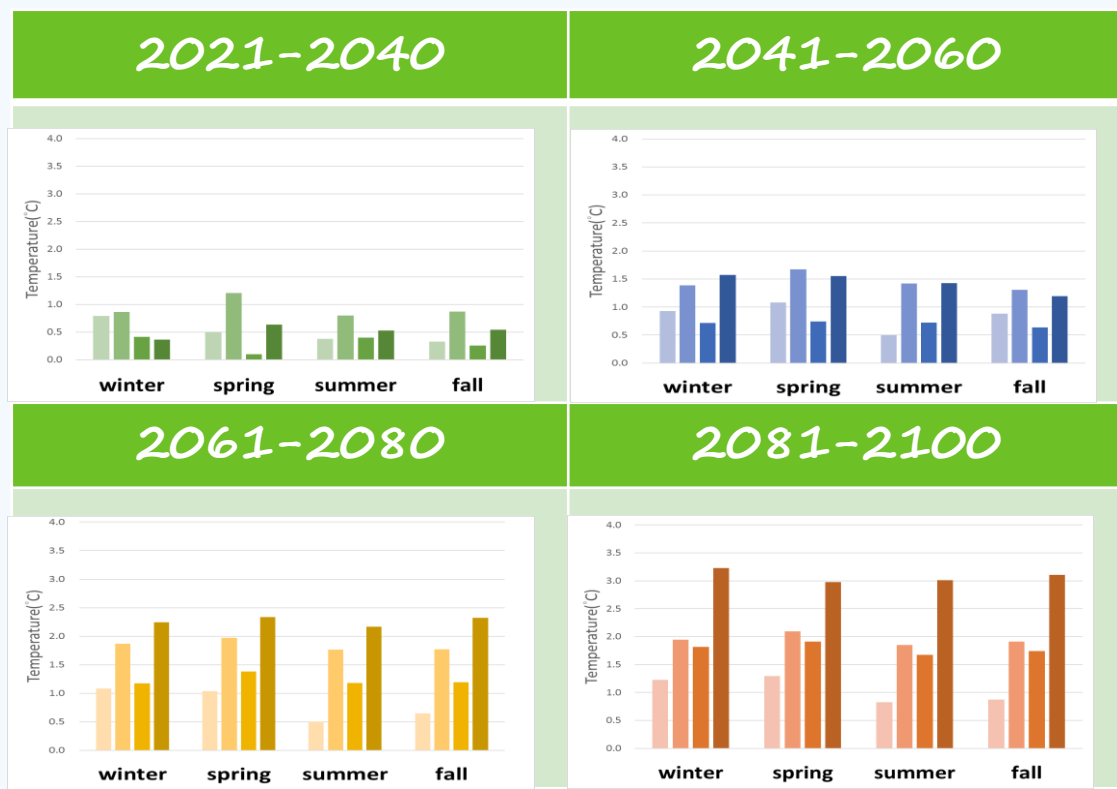


Lowest
increase

Looking into changes of watershed clusters under climate change scenarios

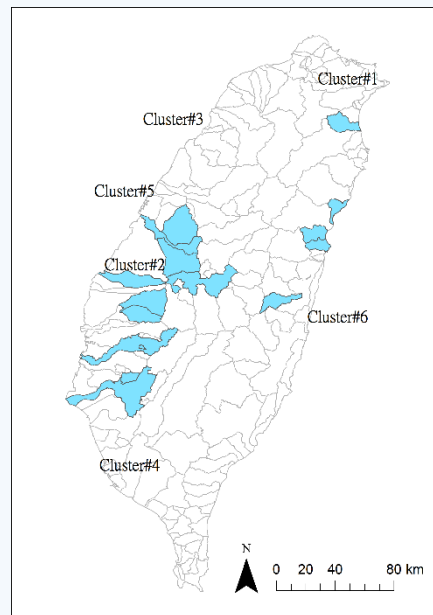
RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temperature - Cluster 2



Increase > 2°C

Increase > 3°C



Lowest increase

Looking into changes of watershed clusters under climate change scenarios

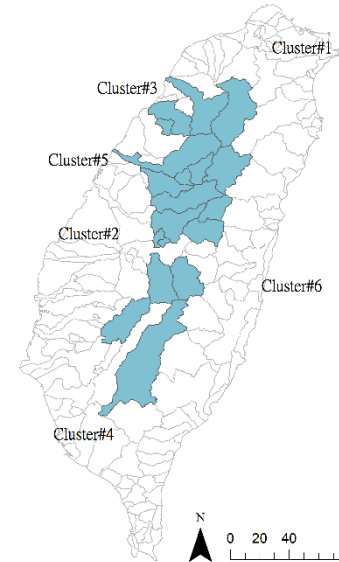
RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temperature - Cluster 3



Increase > 2°C

Increase > 3°C



Legend



Lowest
increase

Looking into changes of watershed clusters under climate change scenarios

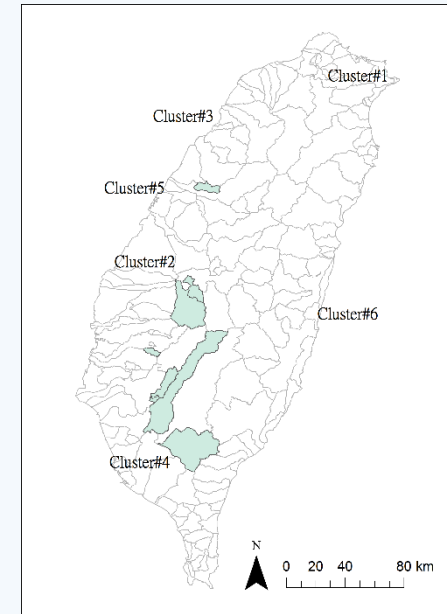
RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temperature - Cluster 4



Increase > 2°C

Increase > 3°C

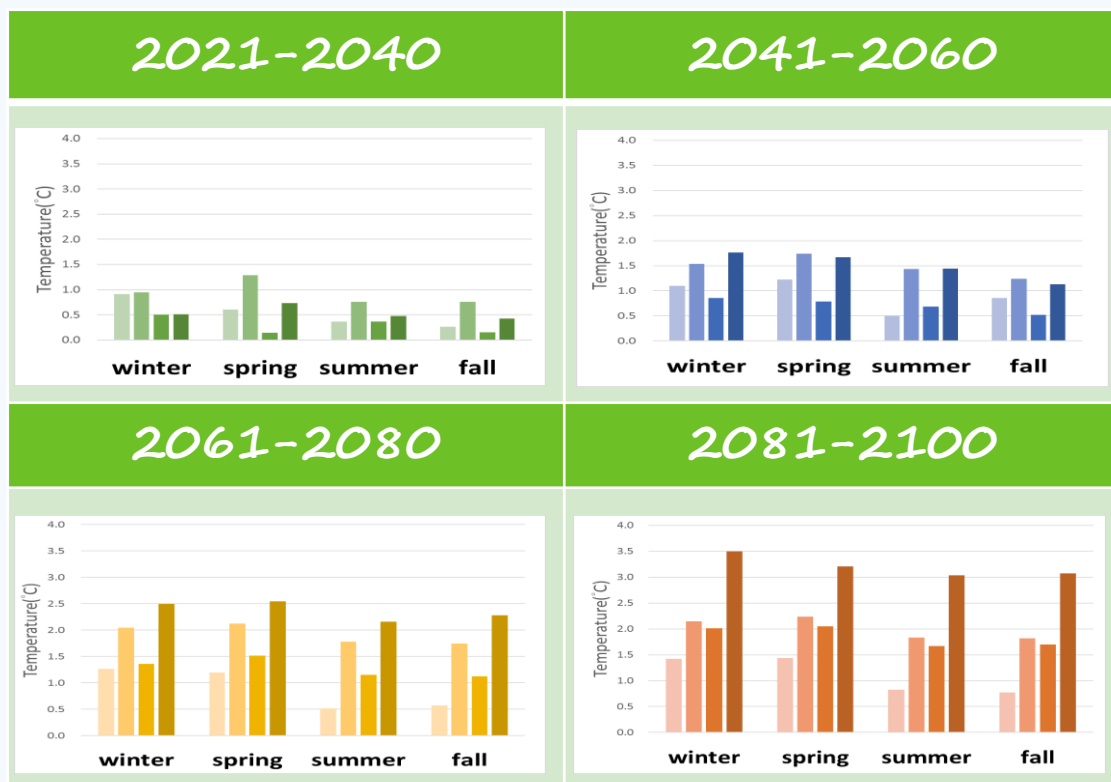


Lowest increase

Looking into changes of watershed clusters under climate change scenarios

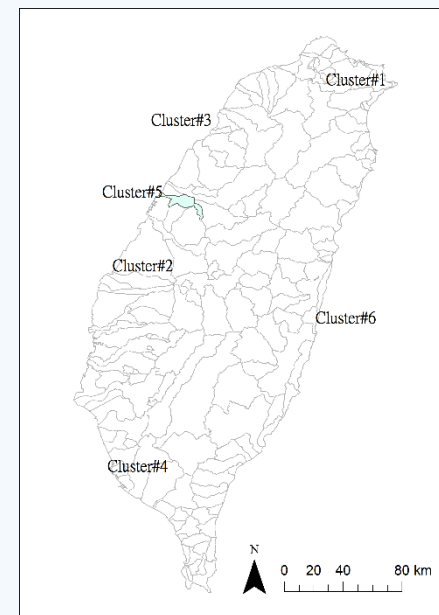
RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temperature - Cluster 5



Increase > 2°C

Increase > 3.5°C



Lowest increase

Looking into changes of watershed clusters under climate change scenarios

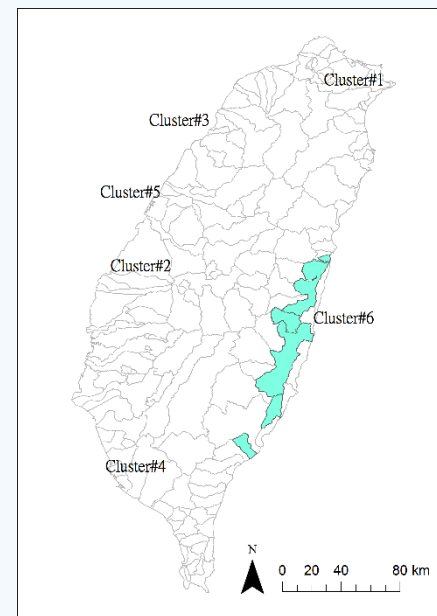
RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temperature - Cluster 6



Increase > 2°C

Increase > 3°C



Lowest
increase

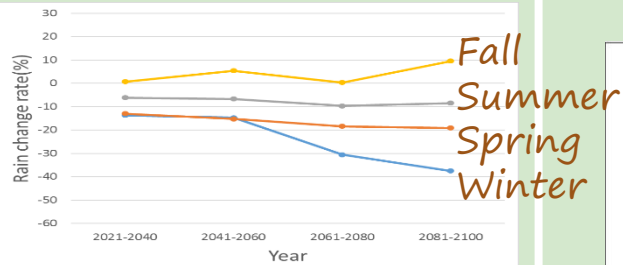
Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

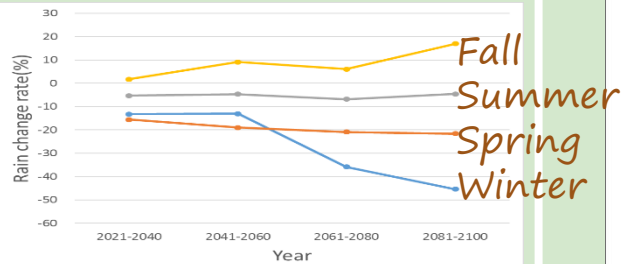


Averaged rain change rate (%)

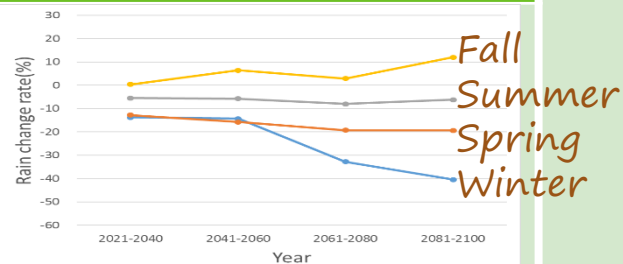
1



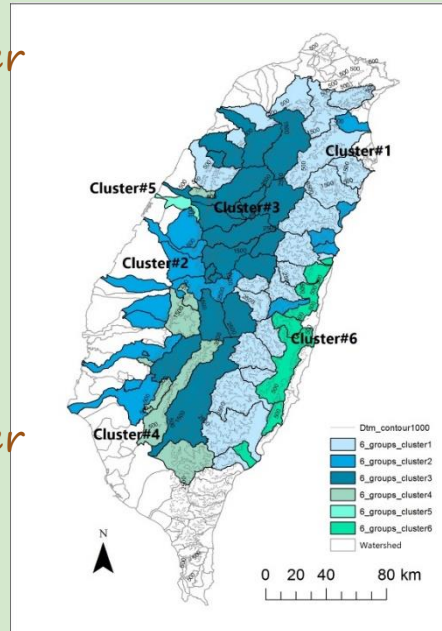
2



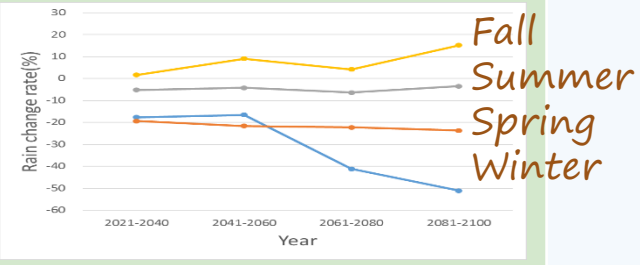
3



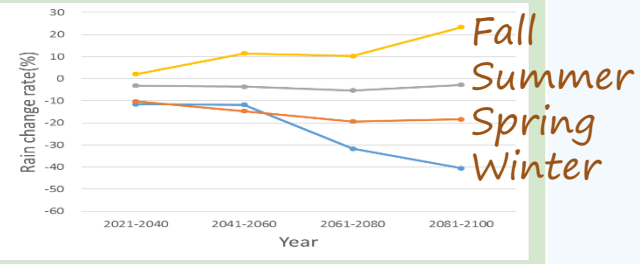
— winter — spring — summer — fall



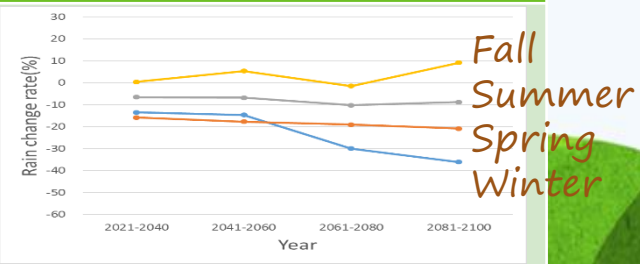
4



5



6



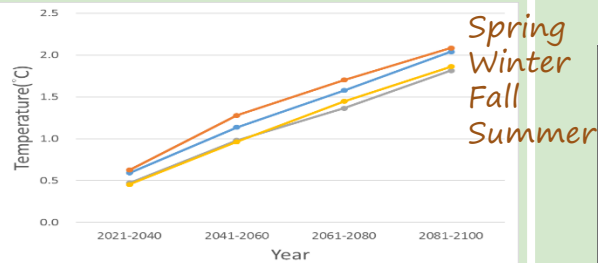
Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

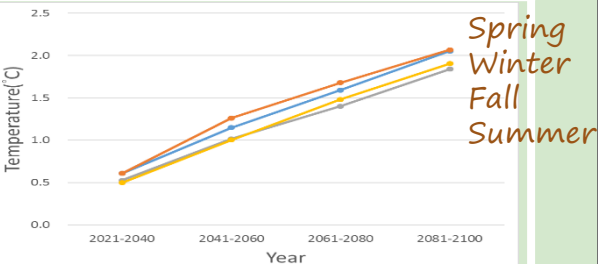


Averaged temperature change (°C)

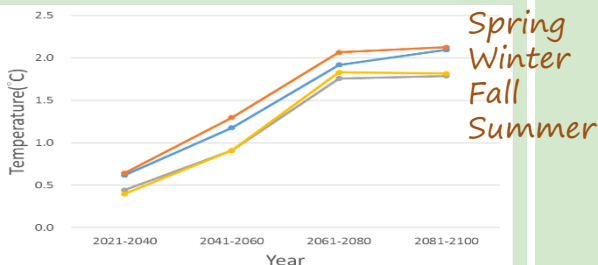
1



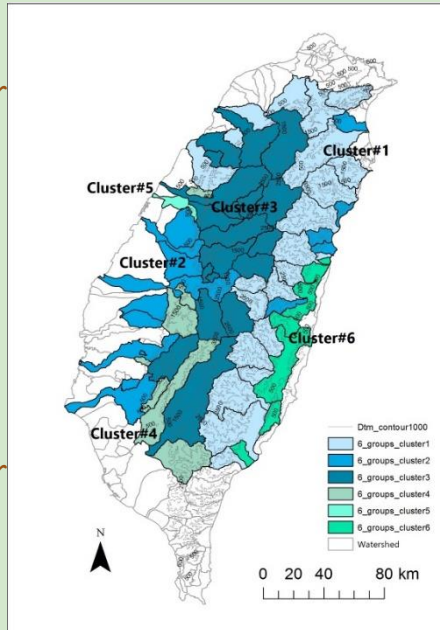
2



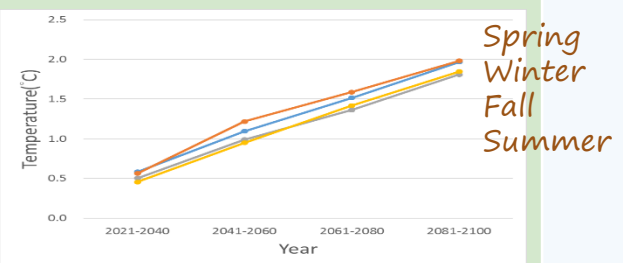
3



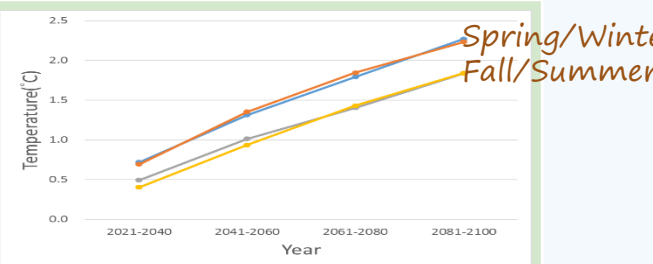
winter spring summer fall



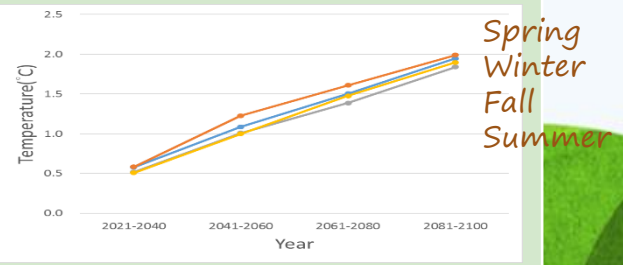
4



5



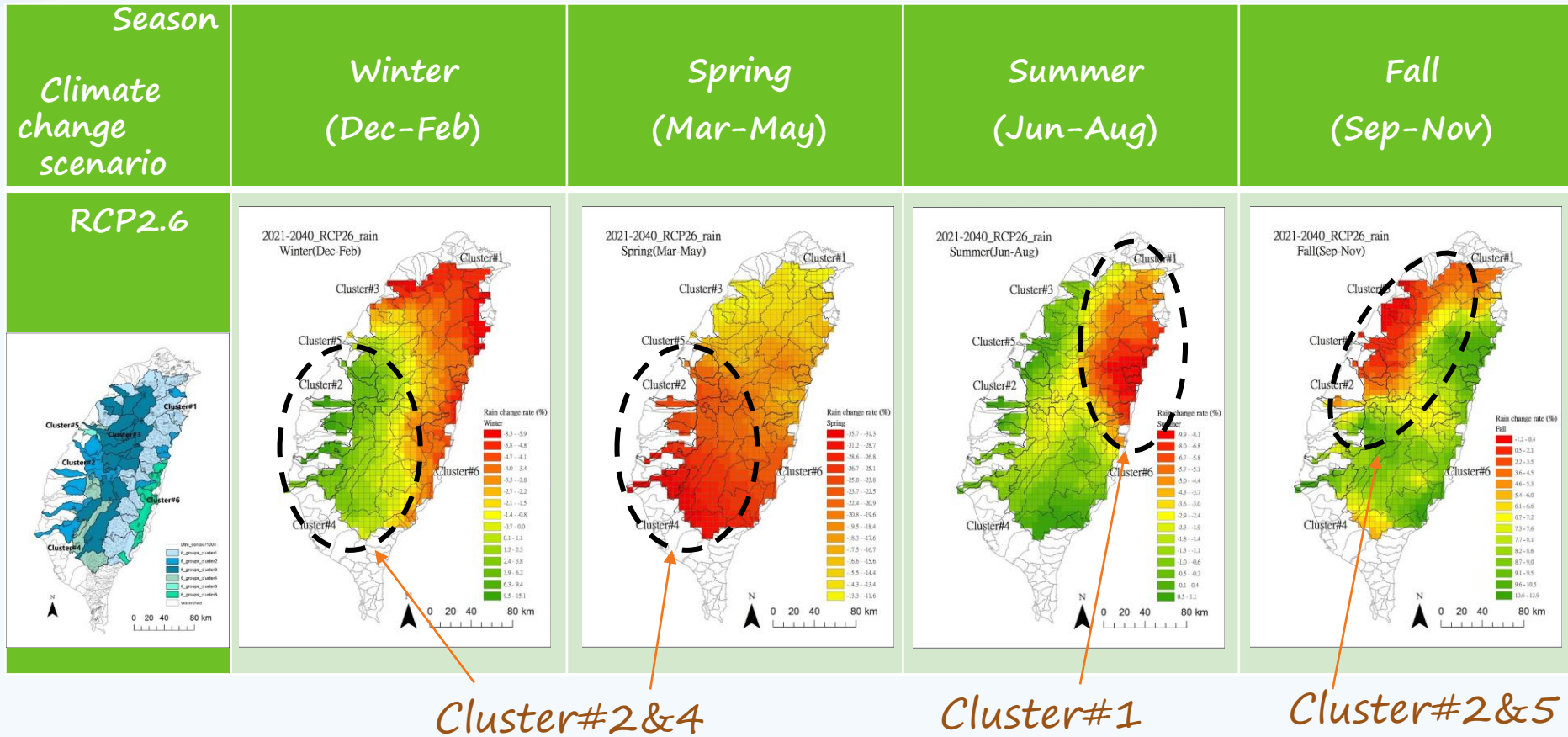
6



Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

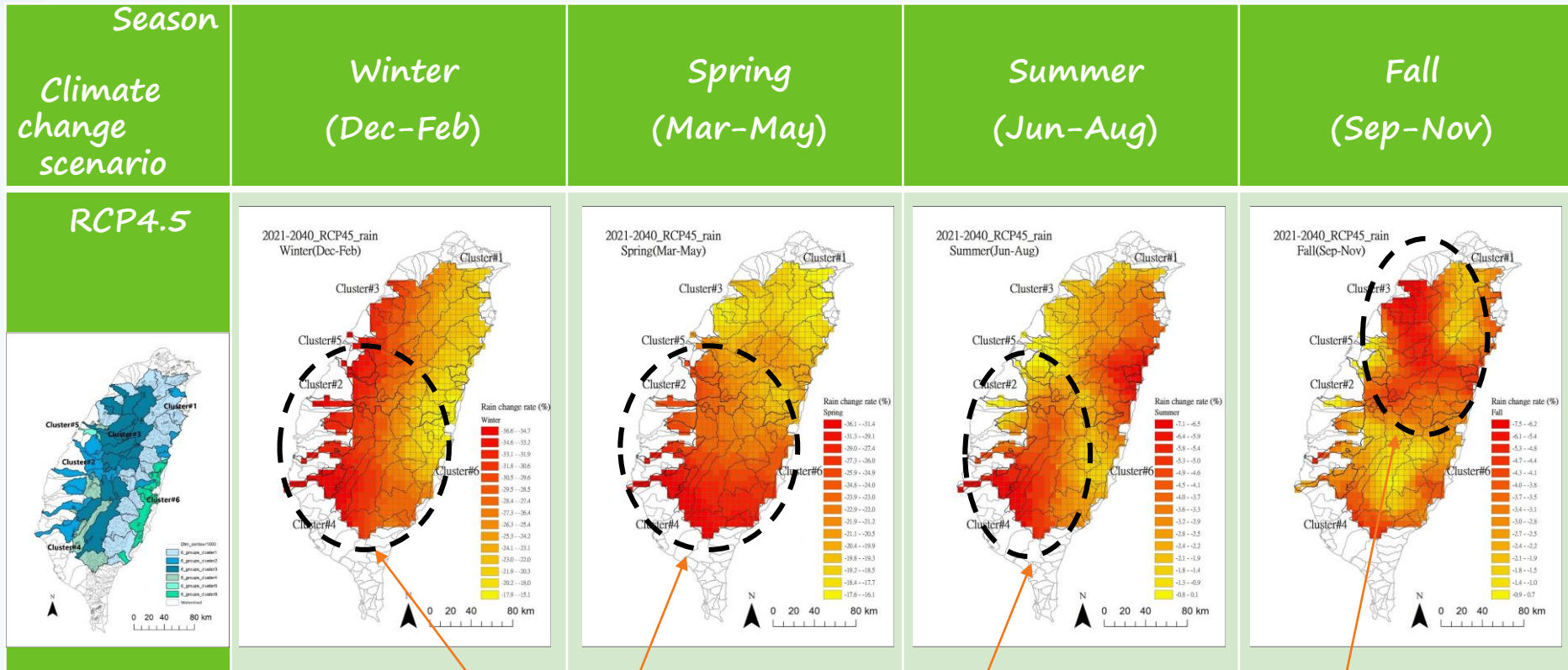
Rain change rate - RCP2.6



Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

Rain change rate – RCP4.5



Cluster#2,3&4
Decreased 36%

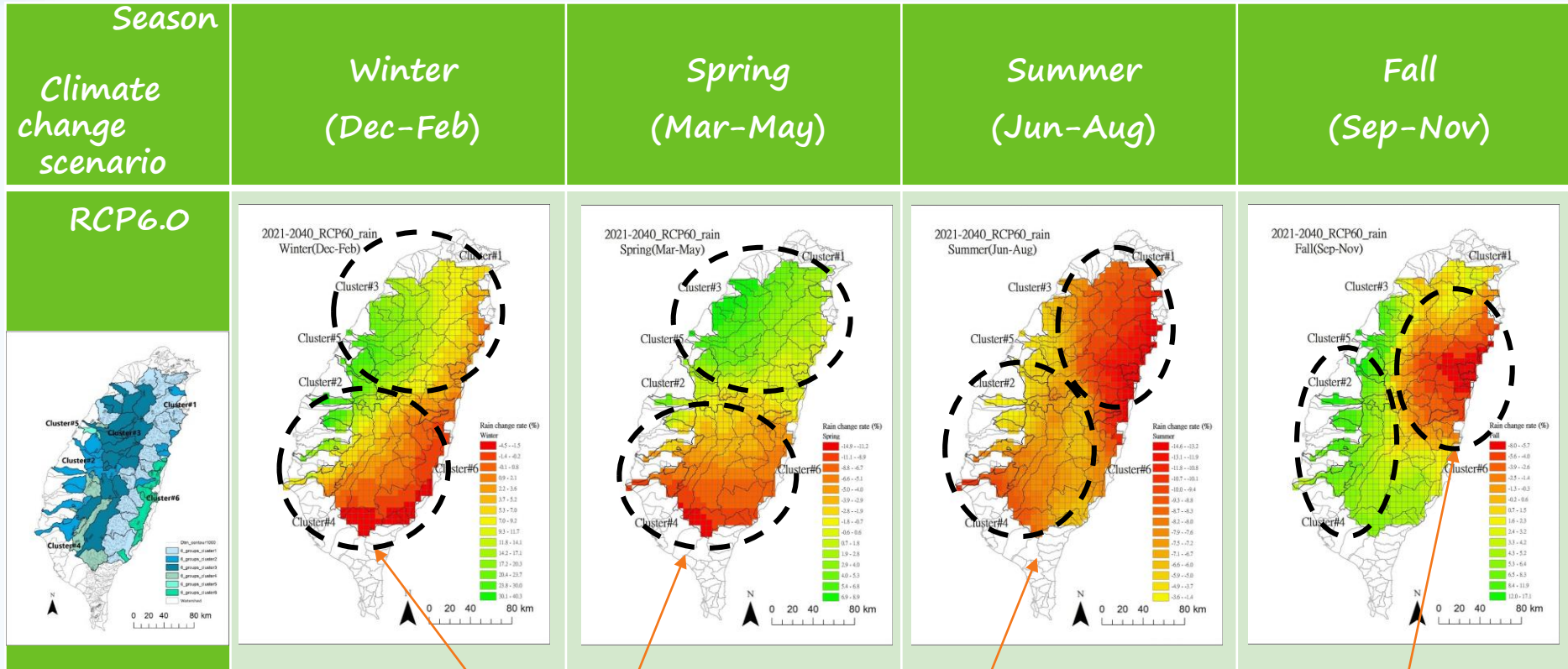
Cluster#2&4

Cluster#3

Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

Rain change rate – RCP6.0



Cluster#1&3: increase→decrease
Cluster#2&4 decrease

Cluster#1,2&4
decrease

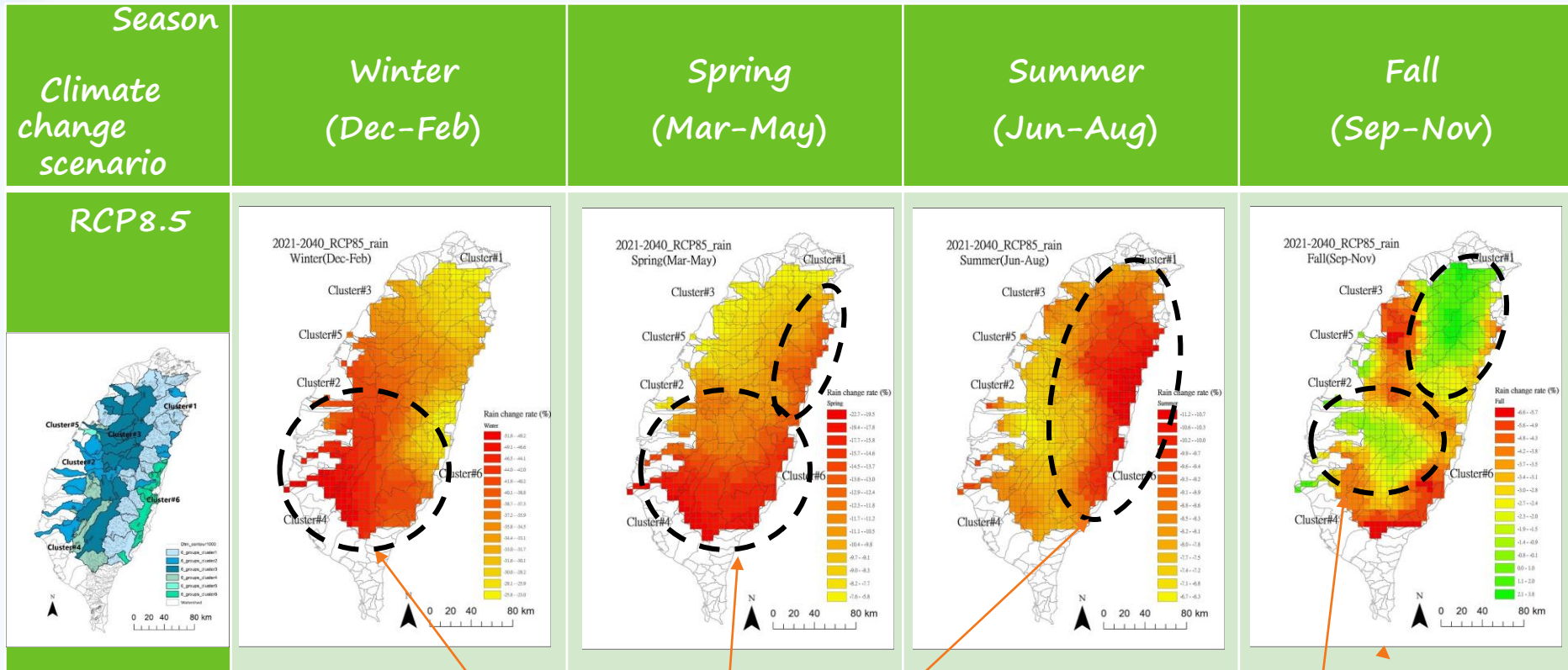
Cluster#1,2
eastern side-decrease

Cluster#2 western side
-increase

Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

Rain change rate – RCP8.5



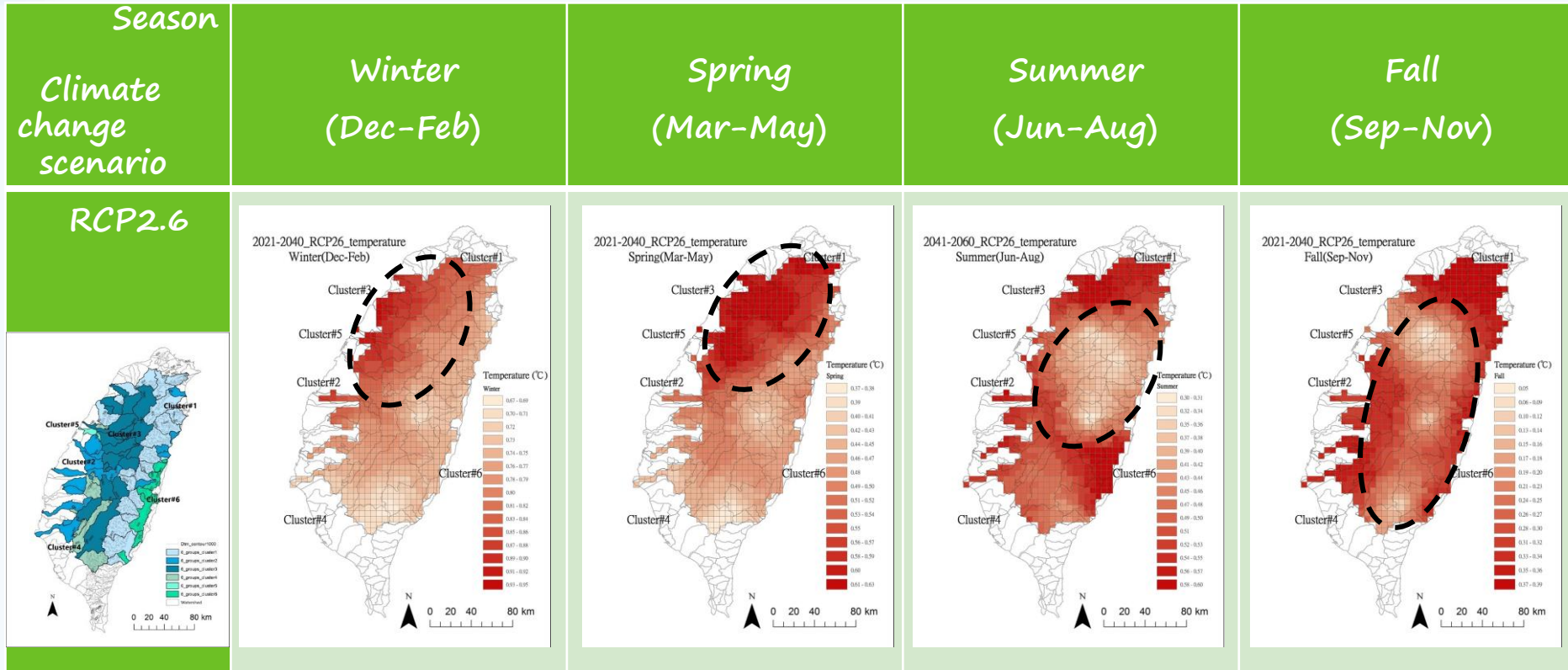
Winter, Spring, & Summer decrease
Especially winter (decrease >50%)
Winter: Cluster#2,3&4 decrease
Spring: Cluster#4&6 , #2 eastern decrease
Summer: Cluster#1&6 decrease

Cluster#1 northern:
increase → decrease
Cluster#3 southern: increase

Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temp change - RCP2.6

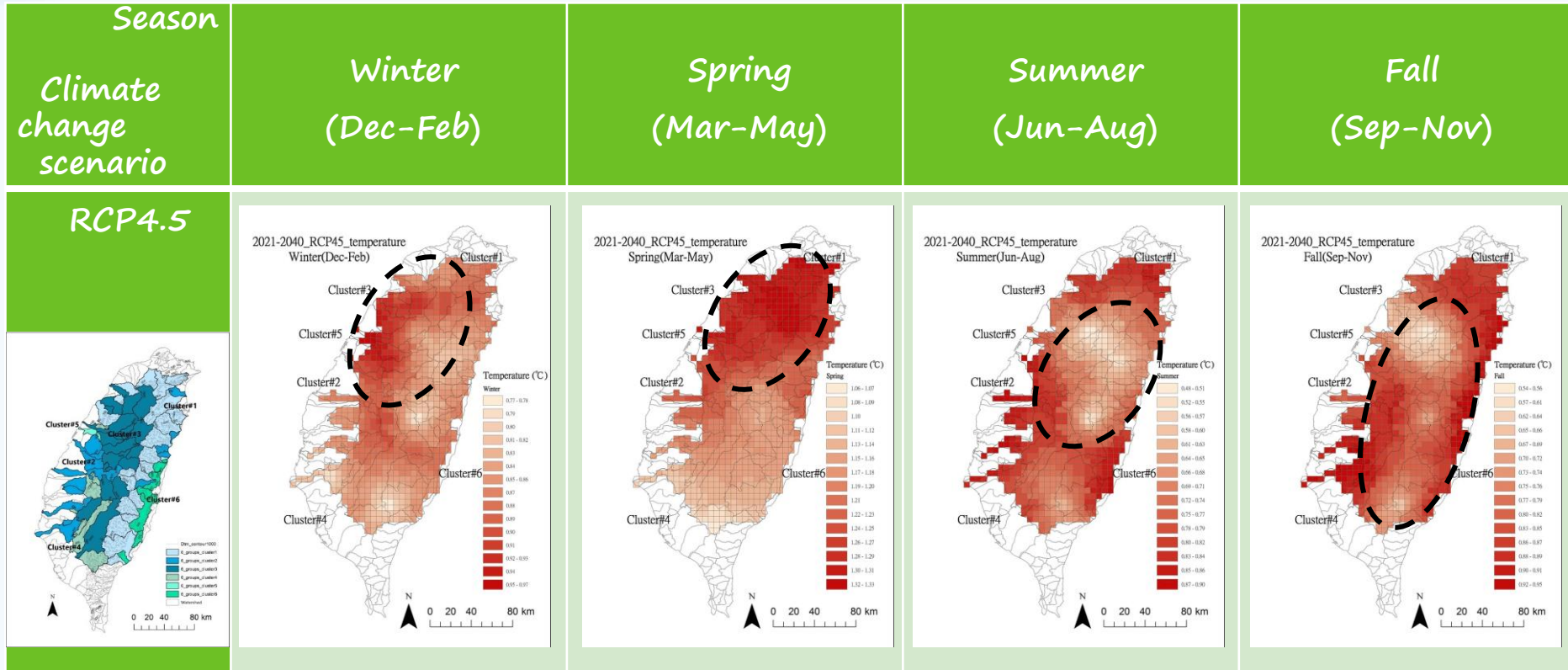


Temp increase all year round
Winter & Spring: NW to SE
Summer & Fall: Central part increase less

Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temp change – RCP4.5

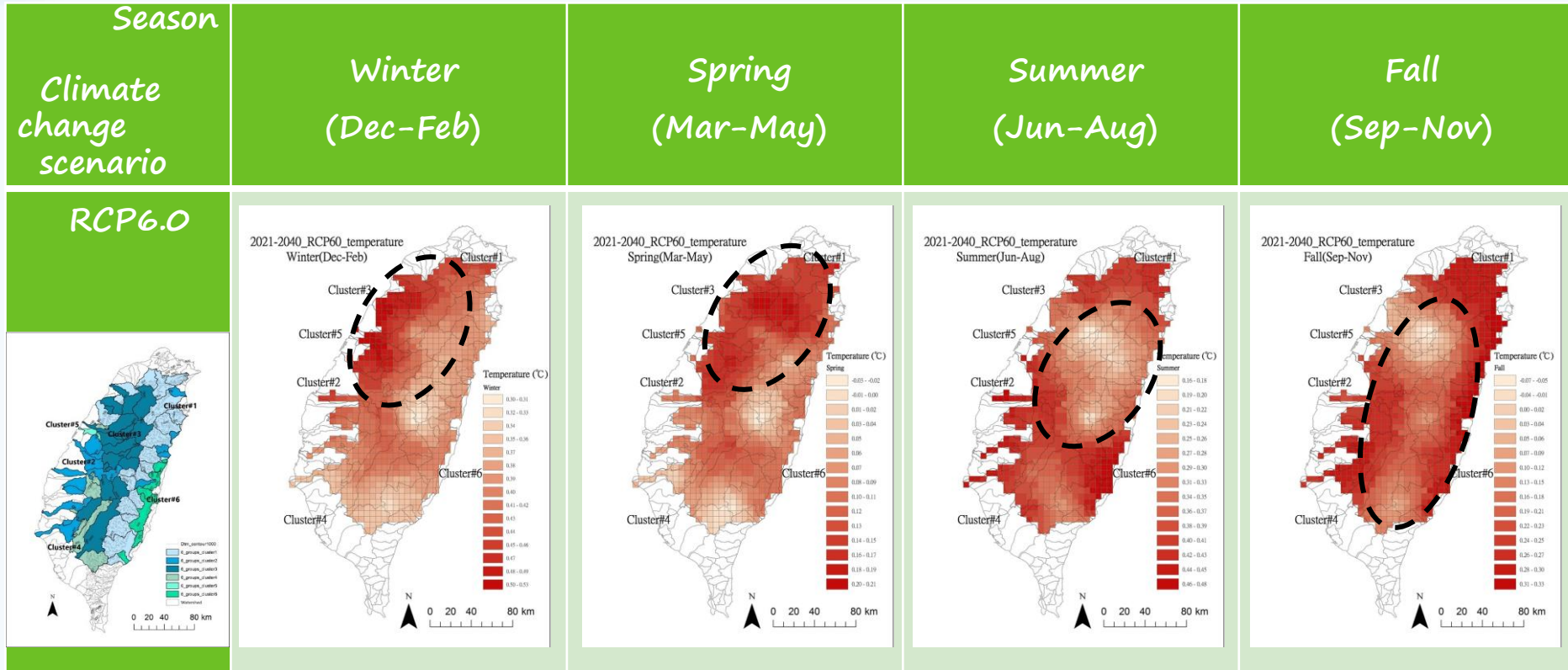


Temp increase all year round
Winter & Spring: NW to SE
Summer & Fall: Central part increase less

Looking into changes of watershed clusters under climate change scenarios

RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temp change – RCP6.0

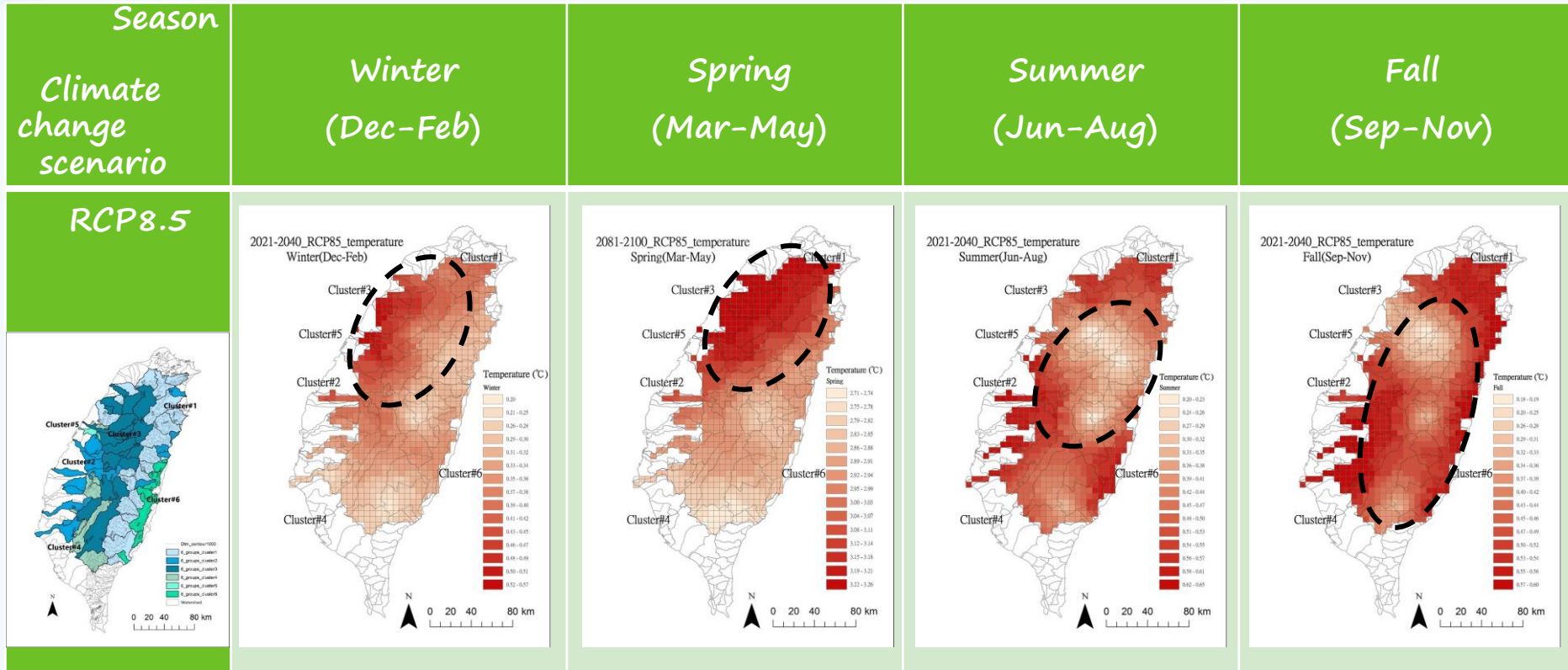


Temp increase all year round
Winter & Spring: NW to SE
Summer & Fall: Central part increase less

Looking into changes of watershed clusters under climate change scenarios

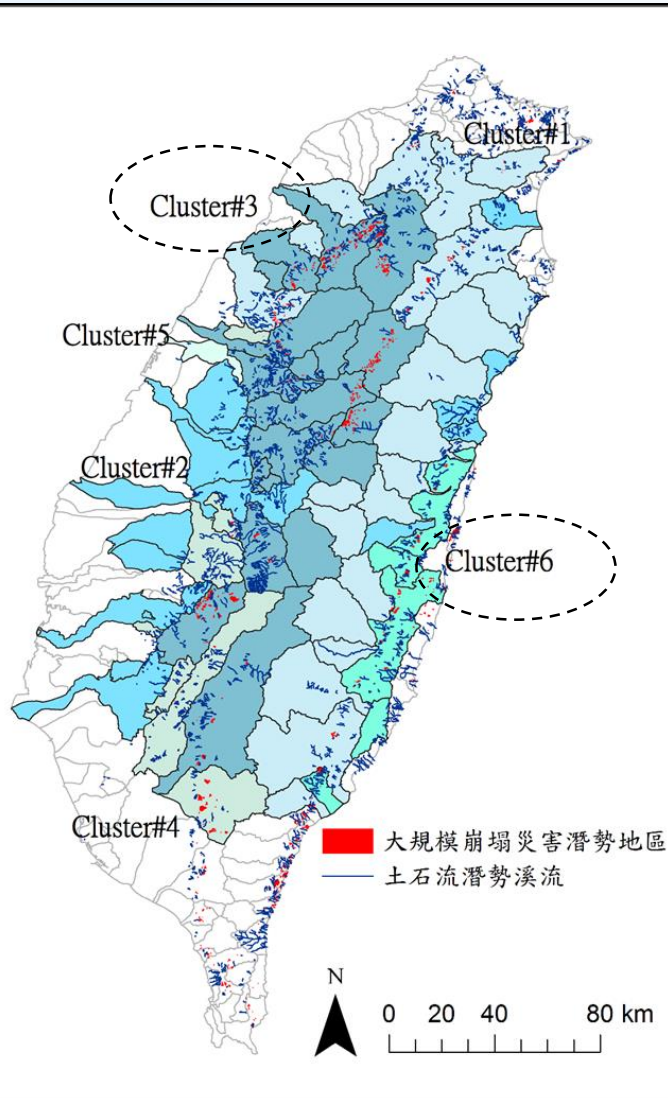
RCP2.6
RCP4.5
RCP6.0
RCP8.5

Temp change – RCP8.5



Temp increase all year round
Winter & Spring: NW to SE
Summer & Fall: Central part increase less

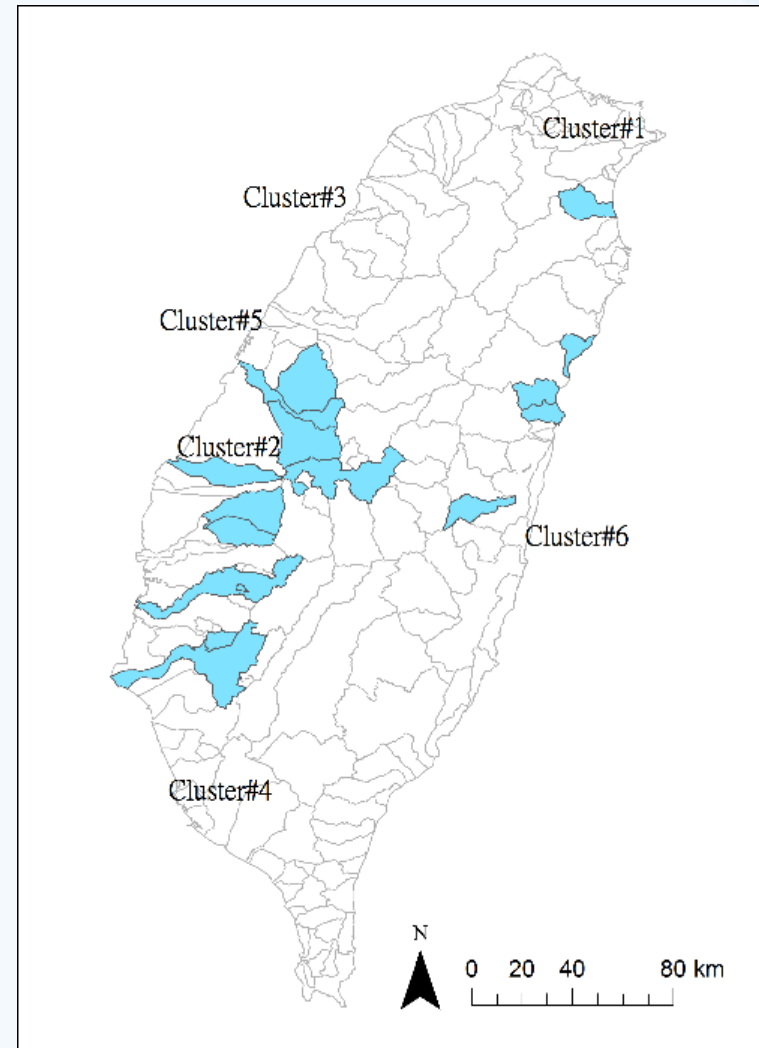
Potential Large-scale collapse disaster area & potential debris flow stream



分群	崩塌災害潛勢面積(公頃)	占分群總面積(%)	土石流潛勢溪流(條)
1	2490.43	0.29	323
2	72.18	0.02	195
3	13075.93	1.66	517
4	1920.20	0.89	150
5	0.00	0.00	6
6	2948.90	1.84	142
Total	20507.64		1333

Adjusting the climate change adaptation strategies

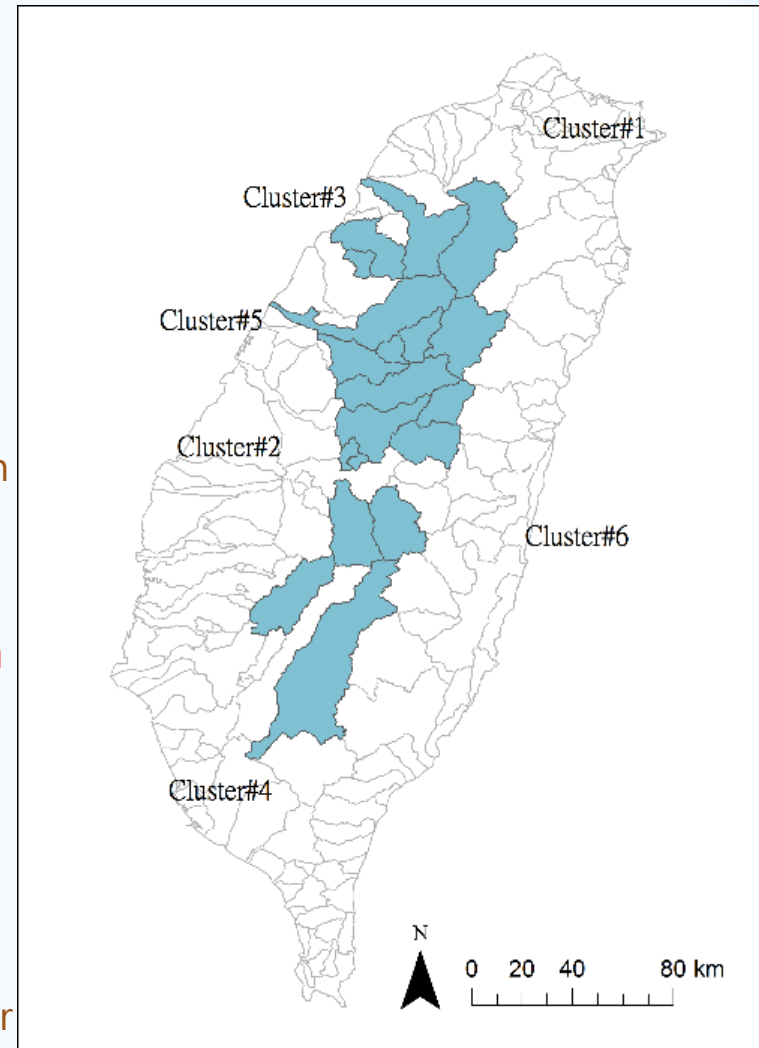
- Cluster#1
 - On the eastern side of the Central Mountain Range
 - NDVI has positive relationship with rain in spring and winter
 - In all scenarios, spring & winter will have less rain and higher temp
 - **Need to consider soil and water conservation especially in spring & winter**
- Cluster#2
 - On the western side of the island
 - 20% decrease in spring rainfall
 - 20% of the land belongs to agricultural land
 - Watch out for the effects of **climate factors (temp increase, rainfall decrease) on crops and water resource usage**



Adjusting the climate change adaptation strategies

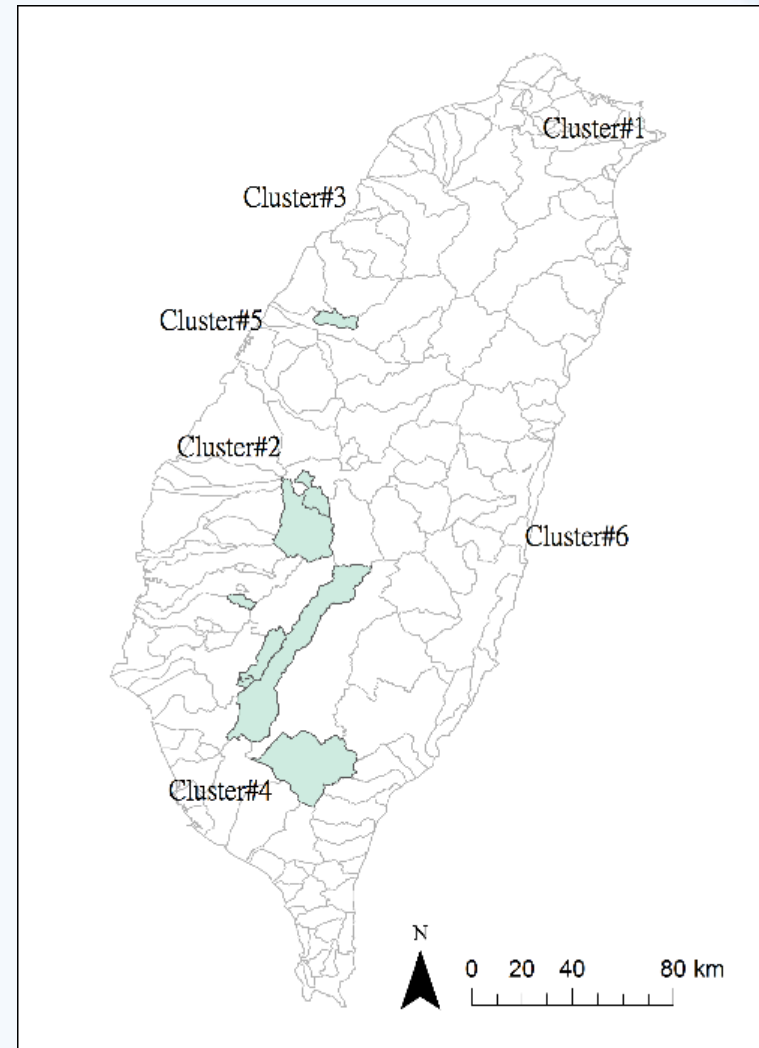
- Cluster#3

- On the western side of the Central Mountain Range
- Spring & winter rainfall has positive relationship with NDVI
- Aug rainfall has a significant negative relationship with NDVI
- Has the largest large-scale collapse disaster area
- Needs to **improve the slope disaster prevention especially on W- and N-facing slope**
- Needs to **enhance the coping capability of large-scale collapse disaster**
- Temperature increasing trajectory reaches its peak at 2061-2080
- Temp increased in summer and fall (but less than other clusters)
- Could be associated with its 75% mixed forest land cover- inferring forest is an important factor in controlling increasing temp



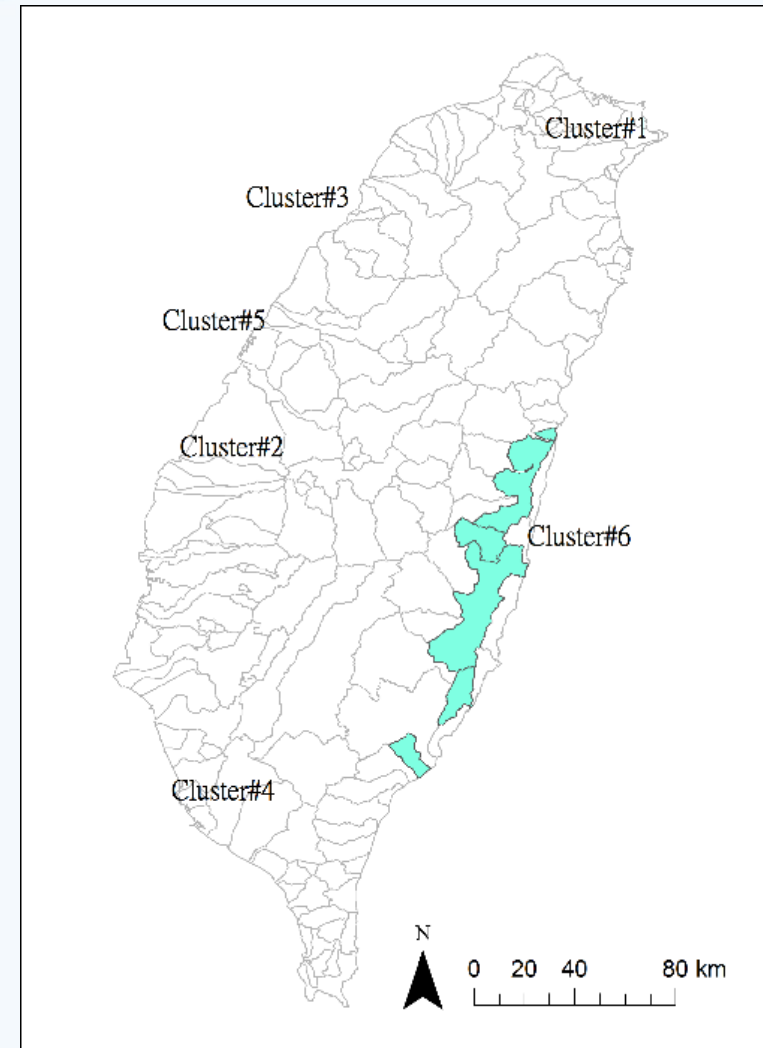
Adjusting the climate change adaptation strategies

- Cluster#4
 - On the west-southern part of the island with higher % of west-facing slope
 - 70% mixed forest
 - 16% agriculture land
 - Rainfall projection reduced 20-50% in winter, spring, and summer
 - Need to consider **the suitability and impacts of agriculture land on the hill or mountain edge**



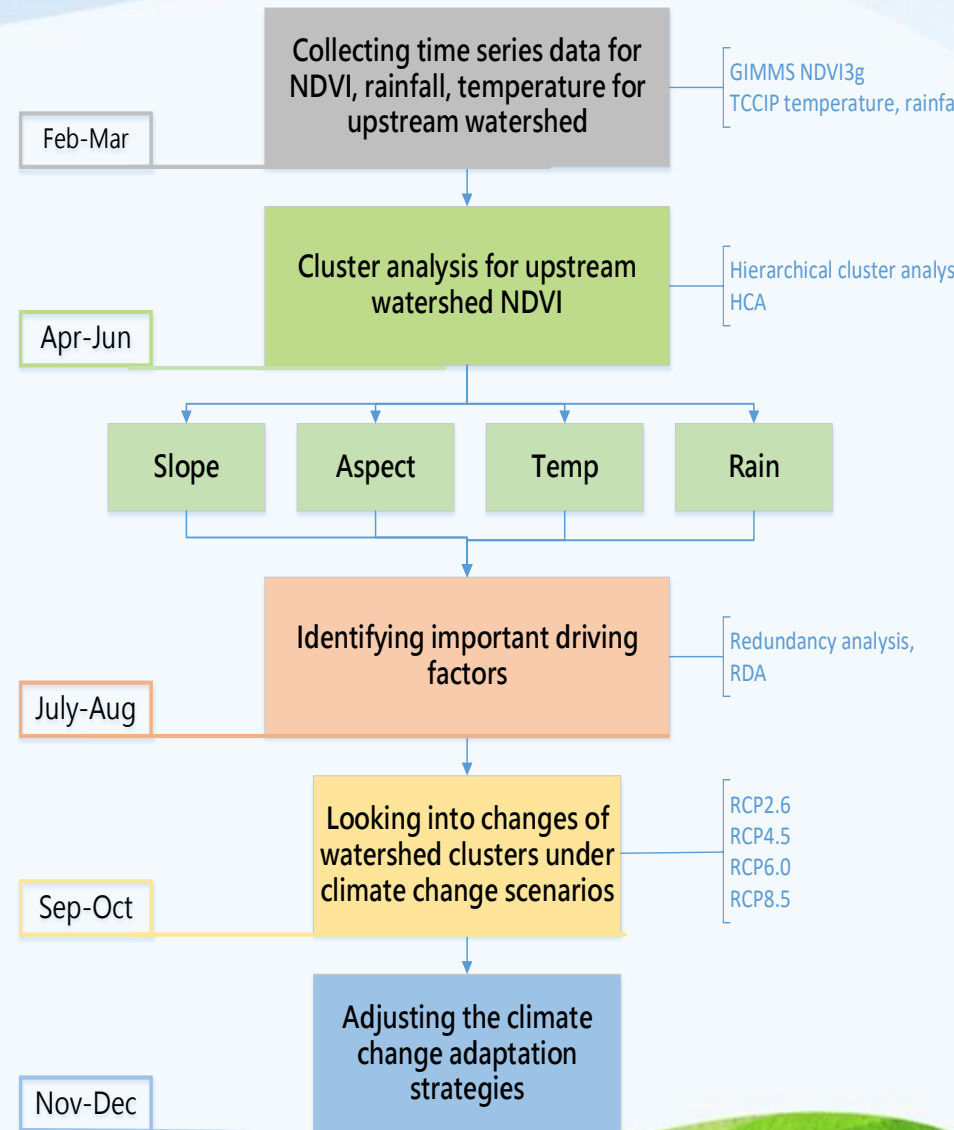
Adjusting the climate change adaptation strategies

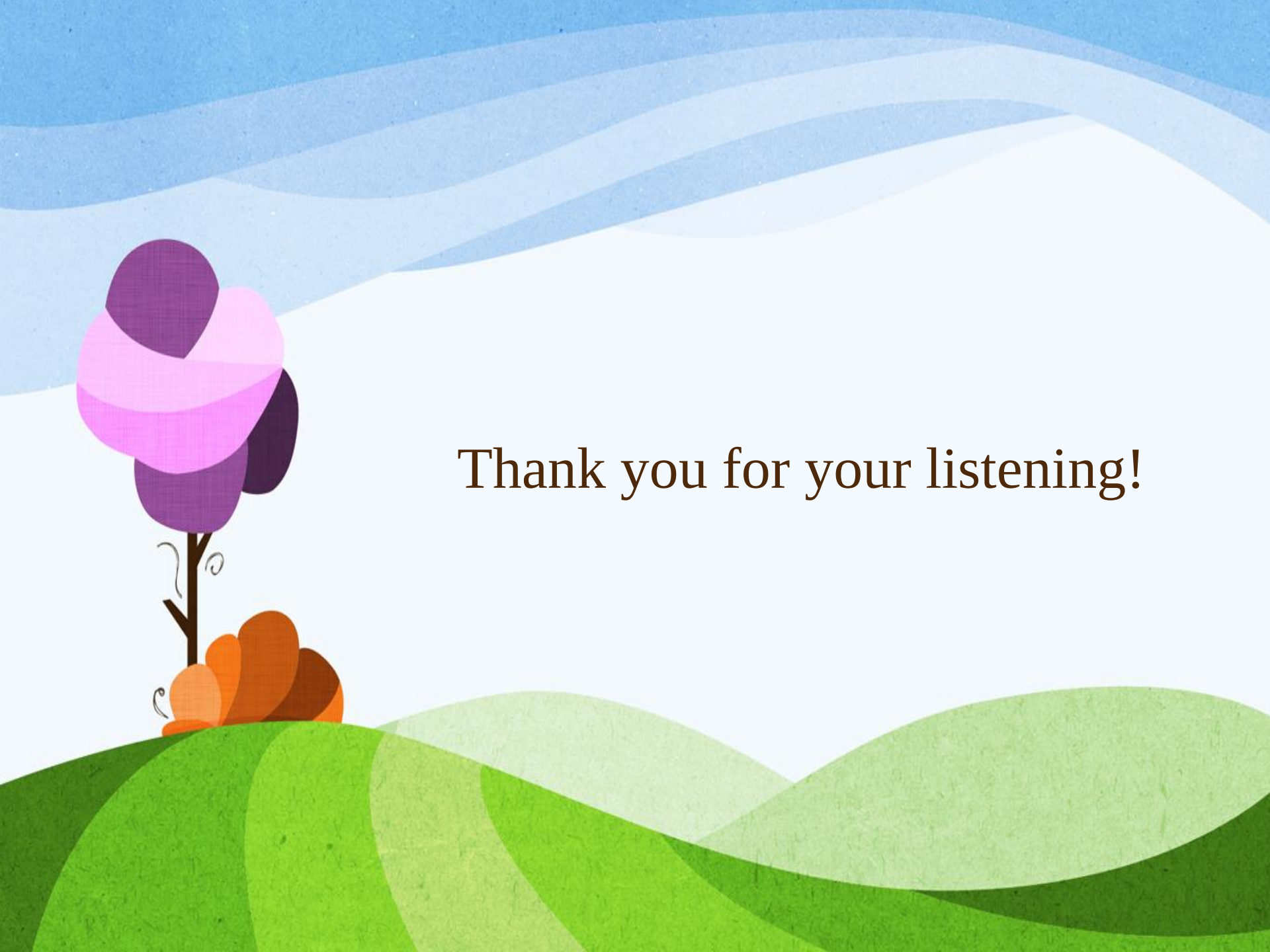
- Cluster#5
 - 28% irrigated land & 22% crop land
 - Decreased winter rain
 - Increased temp in spring and winter
 - Need to consider the **water resources allocation for agriculture**
- Cluster#6
 - Larger % of S, and SE-facing slope
 - Largest area with potential large-scale collapse disaster
 - Need to **enhance the S, and SE-facing slope disaster prevention work and also improve the coping capability of large-scale collapse disaster**



Summary

- Time series data of NDVI, rainfall, temperature were collected
- Cluster analysis results:
 - 6 clusters
- Important driving factors (0.001 sig. level):
 - Slope
 - Temperature
 - Aspects: flat
 - NE facing slope
 - Rainfall
- Climate change scenarios for each cluster
- Adaptation strategies for each cluster



A stylized landscape illustration featuring rolling green hills in the foreground, a small tree with purple and pink foliage on the left, and blue and white wavy hills in the background under a blue sky.

Thank you for your listening!

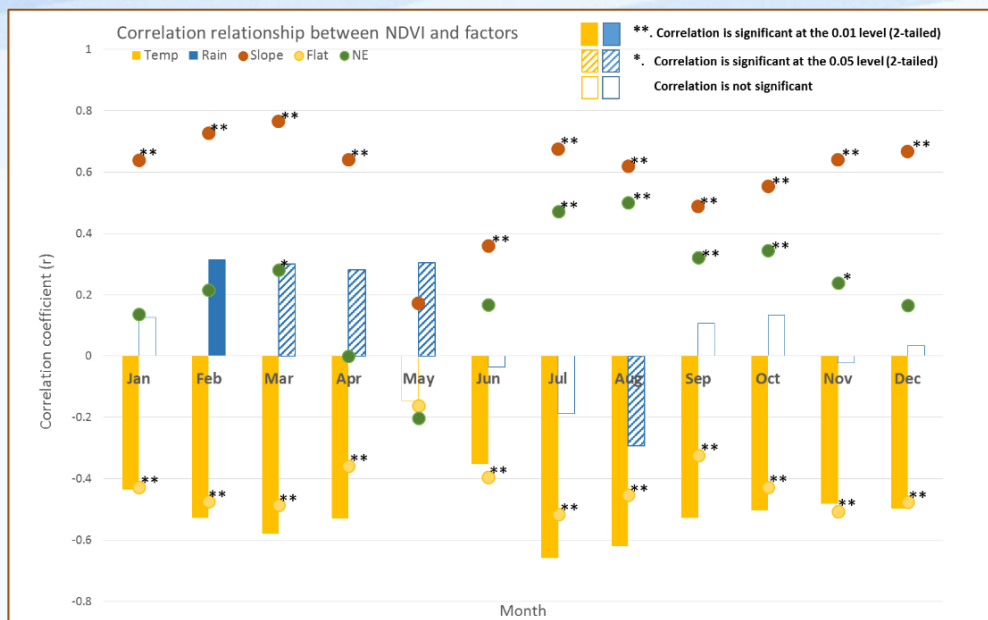


圖 1 各月份NDVI與五項因子(溫度、雨量、坡度、平坦坡與東北向坡)之Pearson相關性分析成果

圖 1為各月份NDVI與具有極高顯著性($p < 0.001$)的五項因子(坡度、溫度、平坦坡(Flat)、東北向坡(NE)及雨量)的Pearson相關性分析成果。坡度因子除了5月之外，和NDVI皆為高顯著性的正相關(0.01 level)，也就是坡度越高NDVI也越高。溫度和平坦坡兩項因子除了5月之外，和NDVI皆為高顯著性的負相關(0.01 level)，也就是溫度越高、平坦坡比例越高則NDVI越低。

東北向坡(NE)因子在7-10月(0.01 level) 和3、4、11月(0.05 level)和NDVI存在正相關關係，顯示出在這些月份中，區域內的東北向坡比例越高其NDVI也越高。

雨量因子在3-5月和NDVI具有顯著正相關(0.05 level)，但在8月份時雨量和NDVI是負相關的。換句話說，3-5月時降雨對NDVI有正面幫助，但8月時降雨越多NDVI越低。

表 1 各月份NDVI與坡度和坡向(9種坡向)之Pearson相關性分析成果

	Slope	Flat	N	NE	E	SE	S	SW	W	NW	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Slope	1																					
Flat	-.592**	1																				
N	-.191	.091	1																			
NE	.398**	-.392**	-.128	1																		
E	.271*	-.273*	-.671**	.700**	1																	
SE	.277*	-.254*	-.790**	.403**	.888**	1																
S	.086	.112	-.518**	-.362**	.007	.318**	1															
SW	.078	-.091	.229	-.569**	-.743**	-.608**	.343**	1														
W	-.229	.015	.485**	-.635**	-.844**	-.802**	-.223	.689**	1													
NW	-.212	-.013	.782**	-.453**	-.810**	-.840**	-.486**	.438**	.849**	1												
Jan	.638**	-.428**	.059	.136	-.078	-.046	-.028	.250*	.133	.096	1											
Feb	.728**	-.474**	-.013	.216	.011	.032	-.017	.206	.058	.020	.977**	1										
Mar	.765**	-.485**	-.076	.281*	.111	.130	-.015	.112	-.046	-.057	.926**	.960**	1									
Apr	.641**	-.358**	-.102	.237*	.115	.154	.096	.069	-.101	-.132	.778**	.815**	.851**	1								
May	.172	-.162	.363**	-.203	-.484**	-.419**	-.023	.471**	.410**	.435**	.545**	.526**	.484**	.527**	1							
Jun	.359**	-.394**	-.178	.167	.164	.215	.012	-.005	-.066	-.060	.404**	.472**	.549**	.605**	.568**	1						
Jul	.675**	-.517**	-.270*	.472**	.415**	.401**	.000	-.151	-.353**	-.275*	.520**	.615**	.691**	.664**	.383**	.844**	1					
Aug	.620**	-.453**	-.209	.501**	.413**	.385**	-.020	-.187	-.404**	-.289*	.430**	.528**	.615**	.612**	.409**	.796**	.961**	1				
Sep	.488**	-.324**	.019	.321**	.111	.108	.041	.053	-.210	-.107	.451**	.521**	.553**	.589**	.672**	.706**	.809**	.883**	1			
Oct	.554**	-.427**	-.031	.345**	.193	.218	.024	-.054	-.215	-.143	.674**	.712**	.725**	.689**	.586**	.544**	.678**	.719**	.785**	1		
Nov	.640**	-.506**	.035	.239*	.050	.086	-.042	.116	-.016	.027	.908**	.918**	.890**	.769**	.605**	.517**	.656**	.608**	.632**	.863**	1	
Dec	.668**	-.476**	.071	.167	-.041	.003	-.023	.206	.076	.083	.964**	.959**	.921**	.774**	.616**	.472**	.591**	.530**	.571**	.806**	.970**	1
** . Correlation is significant at the 0.01 level (2-tailed)																						
* . Correlation is significant at the 0.05 level (2-tailed)																						
Significant positive correlation																						
Significant negative correlation																						

表 1 為各月份NDVI與坡度和坡向(9種坡向)的Pearson相關性分析成果。顯著的正負相關以綠色和紅色標明。就坡度與坡向兩類因子相互關係而言(紅框)，坡度與平坦坡顯而易見為顯著負相關關係；坡度與NE、E、和SE三種坡向具正相關關係。

另外，探討因子與NDVI的相關性(綠框)(表 1)，發現各月份有不同差異，除了NE坡向(上述已討論過)，5月份的NDVI和N、SW、W、NW坡向正相關，但與E和SE呈現負相關。7-8月的NDVI和E與SE正相關，卻和W、NW坡向負相關。北向坡在7月時與NDVI具顯著負相關。由於坡向會影響太陽光輻射與地溫和土壤水分多寡變化，植被生長所反映出的NDVI常見不同。坡向所呈現的月份差異也可推測與臺灣地區5-6月的梅雨和7-8月的颱風季節相關。

表 2 坡度與各月份的溫度及雨量Pearson相關性分析

Slope cor. Temp and Rai	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp	-.886**	-.881**	-.883**	-.904**	-.918**	-.924**	-.919**	-.923**	-.924**	-.915**	-.909**	-.897**
Rain	.347**	.344**	.317**	.321**	.459**	.147	.015	.093	.359**	.322**	.249*	.277*

表 3 各月份雨量與溫度Pearson相關性分析成果

	R_Jan	R_Feb	R_Mar	R_Apr	R_May	R_Jun	R_Jul	R_Aug	R_Sep	R_Oct	R_Nov	R_Dec
T_Jan	-.470**	-.502**	-.457**	-.367**	-.300*	.093	.253*	.180	-.316**	-.378**	-.335**	-.380**
T_Feb	-.484**	-.510**	-.461**	-.361**	-.281*	.121	.278*	.207	-.323**	-.395**	-.352**	-.394**
T_Mar	-.508**	-.518**	-.463**	-.348**	-.273*	.145	.301*	.225	-.351**	-.425**	-.380**	-.420**
T_Apr	-.460**	-.456**	-.404**	-.314**	-.298*	.110	.239*	.187	-.358**	-.417**	-.353**	-.382**
T_May	-.396**	-.395**	-.355**	-.305*	-.344**	.039	.157	.119	-.334**	-.369**	-.295*	-.320**
T_Jun	-.315**	-.326**	-.303*	-.294*	-.380**	-.039	.062	.038	-.293*	-.302*	-.218	-.240*
T_Jul	-.239*	-.265*	-.257*	-.278*	-.396**	-.091	-.007	-.020	-.251*	-.240*	-.147	-.165
T_Aug	-.245*	-.262*	-.250*	-.269*	-.389**	-.086	-.006	-.019	-.264*	-.254*	-.161	-.176
T_Sep	-.308**	-.296*	-.263*	-.244*	-.340**	-.010	.060	.038	-.324**	-.329**	-.237*	-.249*
T_Oct	-.410**	-.374**	-.316**	-.241*	-.285*	.081	.160	.116	-.393**	-.422**	-.343**	-.358**
T_Nov	-.436**	-.415**	-.355**	-.270*	-.278*	.099	.199	.144	-.385**	-.429**	-.359**	-.379**
T_Dec	-.438**	-.448**	-.400**	-.315**	-.284*	.091	.220	.157	-.337**	-.387**	-.332**	-.364**
** . Correlation is significant at the 0.01 level (2-tailed)												
* . Correlation is significant at the 0.05 level (2-tailed)												
Significant positive correlation												
Significant negative correlation												

表 2 為探討坡度與各月份溫度雨量的相關性分析成果。坡度和溫度呈負相關，表示坡度越高溫度越低。坡度和雨量除6-8月之外都呈正相關，表示坡度越高，雨量越多，但夏季(6-8月)除外。

表 3 為各月份雨量和溫度的相關性分析成果。溫度和雨量僅於6-8月呈現正相關，其餘月份大致呈現負相關。

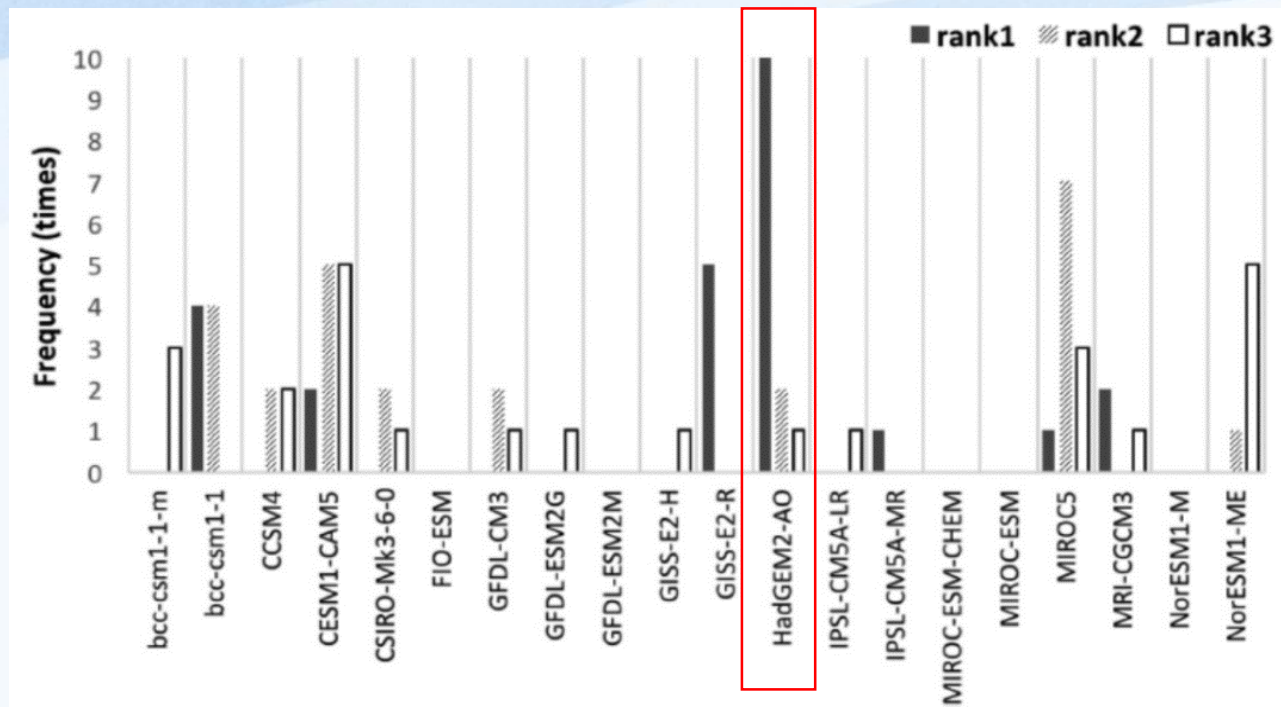


圖 3 適合台灣的GCMs排序(紅框為HadGEM2-AO)

Lin and Tung (2017)以四階段步驟進行選取適合台灣的GCM。步驟一蒐集全台灣25個氣象站歷史月平均降雨紀錄(1986-2005)及20個GCMs(具有完整四個情境預測)。步驟二利用主成分分析(Principle Component Analysis)與集群分析(Cluster analysis)劃分氣候分區。同時依據相關係數以及乾、濕季的正規化均方根誤差(NRMSE)評估此20個GCMs的適用性(applicability)，GCM的。步驟三以加權平均排名(Weighted Average Ranking, WAR)、扣分制度(Demerit Point Systems, DPS)方法將每個氣象站與氣候分區的GCMs排序。步驟四產製每個氣候分區的GCMs適用性列表並與Knutti *et al.* 2013的GCM family tree結果相比對(圖 2)。經過審慎評估與計算排名，在25個氣象站中，HadGEM2-AO排名第一的次數高達10次(圖 3)，因此本計畫優先採用HadGEM2-AO進行各分群集水區之氣候變遷情境分析。