Environmental Impact Assessment (Draft)

May 2018

PRC: Yunnan Lincang Border Economic Cooperation Zone Development Project
(Annexes: Appendix 3 – Climate Risk and Vulnerability Assessment Report)

Prepared by Lincang Border Economic Cooperation Zone Development Project, People's Republic of China for the Asian Development Bank.

CURRENCY EQUIVALENTS

(as of 15 May 2018)

Currency Unit	–	yuan (CNY)
CNY1.00	=	$0.158
$1.00	=	CNY 6.340

NOTE

In this report, “$” refers to US dollars.

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APPENDIX 3

PRC: Yunnan Lincang Border
Economic Cooperation Zone Development
Project (49310-002)

PROJECT PREPARATORY TECHNICAL ASSISTANCE

CLIMATE RISK AND VULNERABILITY ASSESSMENT REPORT

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ANNEXES

Annex A: Advances in the Research of Yunnan's Arid Climate and Extreme Drought

I. OVERVIEW

A. Background

1. Climate Risk and Vulnerability Assessment is a part of the Final Report of Project Preparatory Technical Assistance (PPTA) for preparing finalizing Yunnan Lincang Border Economic Cooperation Zone Development Project (The project). The project is a co-financed project initiated by Asian Development Bank (ADB) and the Government of Yunnan Province. The project activities are dispersed in the territories of Lincang Municipality.

2. As China's 16th border economic cooperation zone, the Lincang Border Economic Cooperation Zone in southwest Yunnan province was approved in 1992. Since its inception in 2011, the Lincang economic zone has focused on cross-border trade, logistics, finance, tourism, equipment manufacturing and more, facilitating China-Myanmar cooperation. This project is ADB's investment response to the local demand of a piloting modern and environmental friendly border cooperation zone.

3. The project is expected to produce 4 outputs: (i) Cross-border capacity improved; (ii) Integrated urban environmental infrastructures in Qingshuihe border area Improved; (iii) Social infrastructure and service improved; (iv) Institutional capacity of involved agencies Improved:

Output 1. Cross-border capacity improved. This output is aimed to improve human living quality, efficiency of industrial activities and convenience of cross border transportation in Qingshuihe area. It includes Qingshuihe Border Trade Facilities construction and road paving in the border zone.

Output 2. Integrated urban environmental infrastructures in Qingshuihe border area Improved. This output is aimed to improve the entire performance of the environmental infrastructures in Qingshuihe cross border area. It includes potable water supply system, wastewater treatment facilities, municipal waste treatment system, River rehabilitation and new energy connecting points.

Output 3. Social infrastructure and service improved. This output is aimed to increase education and medical capacity of the cross border zone. It includes construction of schools and hospitals.

Output 4. Institutional capacity of involved agencies Improved. This output does not involve any constriction or engineering work.

B. Project Components

ADB and Yunnan Province agreed officially the following project components according to above mentioned 4 outputs. :

Tab.01 –Summary of Project Components

No Description	Type/ Classification	Unit	Quantity
1. Cross-border capacity improved			
A Qingshuihe Border Trade Facilities			
1 Border resident trade market	Market	m^2	93,072
2 International Cooperation Area	Industrial park	m^2	171,633
B Qingshuihe Border & Trade Infrastructures			
1 Qingshuihe Border Area Branch Roads Secondary	Secondary/branch	m	5,070
No 1 Road	Branch	m	900
No 2 Road	Branch	m	788
No 3 Road	Branch	m	1,260
No 3 Road Bridge over Qingshui River	3x40 m steel box girder		
No 4 Road	Branch	m	644
No 5 Road	Branch	m	955
2 Nanting River Bridge		m	350
Main: 3 span twin tower cable stayed bridge (70+140+70)	S. Approach: 3x20 m prestressed T beam		
No 6 Road	Class II	m	523
2. Integrated urban environmental infrastructures in Qingshuihe border area Improved			
A Qingshuihe Border Area Water Supply System			
Water intake Nangui River		m^3/d	21,000
Water transmission line	DIP Pipe	m	32,000
Water treatment plant	Conventional	m^3/d	20,000
Water distribution network	PE & DIP	km	28,100
B Qingshuihe Border Area Wastewater Treatment System			
WWTP		m^3/d	10,000
Wastewater piping network	HDPE & Conc m		7,200
C Qingshuihe Border Area and Mengding MSW Management			
Transfer station (horizontal compression)		27t/d	1
Collection station at logistics area		7 t/d	1
Collection station at corporation area		8 t/d	1
MSW collection station with toilet			6
MSW equipment:		set	1
D Qingshuihe Border Area River Rehabilitation			
Qingshui River		m	3,431
Nanpa River		m	?
Sewage interception (frp pipe with manholes)		m	?
Landscaping		m^2	106,733
Grey water from WWTP recharge pipe		m	?
E New Energy Public Transport Facilities			
Qingshuihe electric charging station		mu	12
Mengding electric charging station		mu	10
New energy bus		ea	6
3. Social infrastructure and service improved			
A Education Facilities			
Cangyuan Guomen No 2 Elementary School	New	m^2	18,311

Qingshuihe Guomen Elementary School Upgrade	Upgrade	m^2	7,691
B Hospitals			
Zhenkang Sino-Myanmar Friendship Hospital	New	m^2	56,009
Qingshuihe Hospital	New	m^2	8,946
4. Institutional capacity of involved agencies Improved			
A Project and contract management B Environmental, resettlement, social and minority plan implementation and monitoring C Border trade and logistics capacity building D Teacher training and school leadership E Healthcare service and hospital management F RCI development and capacity building			

4. All project activities are dispersed in the territory of Lincang Municipality.

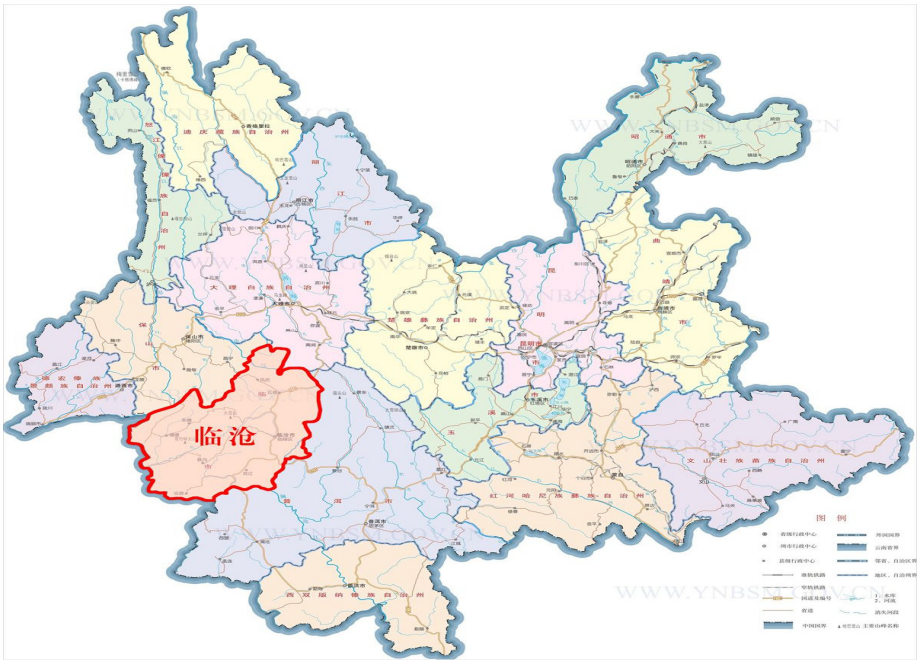


Figure 1: Lincang Municipality in Yunnan Province

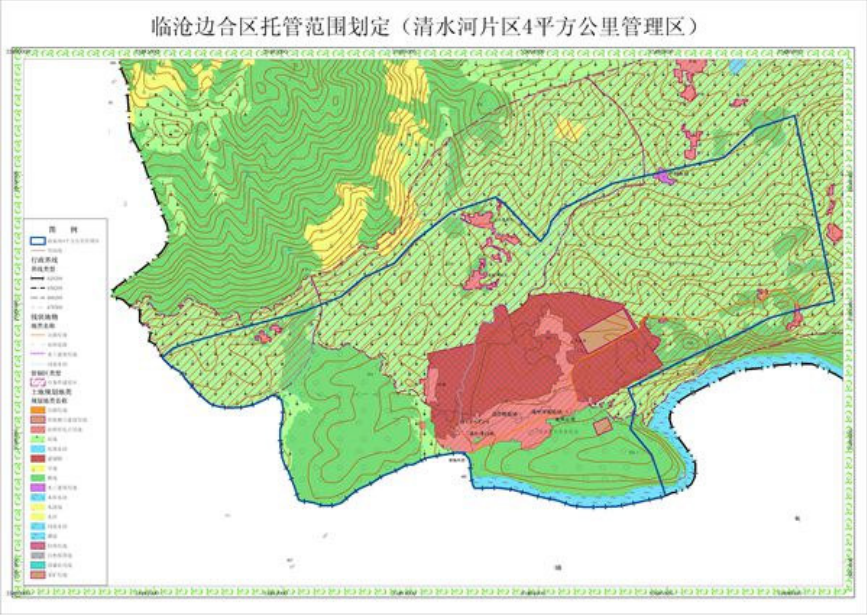


Figure 2: Qingshuihe cross border zone in Lincang Municipality

A. Climate Screening

5. The potential for the infrastructures and activates to be affected by future climate change was considered in: ADB Report, Climate-Related Disasters in Asia and the Pacific; World Bank Report, Climate Trends and Impacts in China; and Local Report, Characteristics of Droughts and Floods Analyzed Using the Standardized Precipitation Index in Yunnan Province During the Past 55 Years; etc. An abstract of climate change narrative written by professors of National Key Laboratory in Peking Normal University is attached as Annex A.

6. The screening identified **lack of precipitation/drought** as **a major risk** affecting project sitting/design, construction, maintenance and performance. Drought may cause difficulties in water supply and daily operation of project activities both in domestic and industrial zones. Drought may cause vegetation degradation and biodiversity degradation.

7. The screening identified extremely intense precipitation and flood as **a major risk** affecting project design, construction, maintenance and performance. Especially, extremely intense precipitation causes considerable damages to construction sites and waste management facilities (both construction phase and operational sites). Extremely intense precipitation and flood can disturb regular operation and maintenance human resource arrangement, in case the project sites have access difficulties.

8. The screening identified extremely high temperature **as a minor risk** affecting project sitting/design, construction, maintenance and performance. High temperature may cause shorter service duration of materials such as landfill liners. High temperature may cause difficulties in operation and maintenance arrangements for project facilities.

9. The screening identified extreme low temperature as **a negligible risk** affecting project sitting/design, construction, maintenance and performance. The lowest temperature recorded by modern methodology in Yunnan Province is – 7.8 Degree Celsius. Low temperature, below – 10 Degree Celsius, may causes damages to buildings during construction phase by low cement solidification. Civil works in winter shall follow the national technical code: JGJ/T 104-2011 Specification of winter construction of building engineering.

10. The screening summarized the potential climate risks as follows:

Tab.02 –Climate Risks Screening

Location and Design of project	Project construction sites and operational sites can be affected by floods.
Output 1. Cross-border capacity improved. This output is aimed to improve human living quality, efficiency of industrial activities and convenience of cross border transportation in Qingshuihe area. It includes Qingshuihe Border Trade Facilities construction and road paving in the border zone.	Project construction sites and operational sites can be affected by floods. Extremely intense precipitation causes considerable damages to construction sites, especially road paving workplaces. Extremely intense precipitation and flood can damage operational project facilities within the project boundary. Extremely intense precipitation and flood can disturb regular operation and maintenance human resource arrangement, in case the project sites have access difficulties. Drought may cause difficulties in water supply for construction sites resulting project implementation delays. Drought may cause difficulties in water supply and daily operation of project activities both in domestic and industrial zones.
Output 2. Integrated urban environmental infrastructures in Qingshuihe border area Improved. This output is aimed to improve the entire performance of the environmental infrastructures in Qingshuihe cross border area. It includes potable water supply system, wastewater treatment facilities, municipal waste treatment system, River rehabilitation and new energy connecting points.	Facilities on project sites can be damaged during violent precipitation events and consequential floods. Extremely intense precipitation causes considerable damages to waste collection/ wastewater collection sites with flooding and waste/wastewater overflow. Extremely intense precipitation and flood can disturb regular operation and maintenance human resource arrangement, in case the project sites have access difficulties. Drought may cause difficulties in water supply for construction sites resulting project implementation delays. Drought may cause difficulties in water supply and daily operation of project activities both in domestic and industrial zones.

Output 3. Social infrastructure and service improved. This output is aimed to increase education and medical capacity of the cross border zone. It includes construction of schools and hospitals	Facilities on project sites can be damaged during violent precipitation events and consequential floods. Extremely intense precipitation and flood can disturb regular operation and maintenance human resource arrangement, in case the project sites have access difficulties. The normal function of school and hospitals will be impacted very considerably by floods. Extremely high and extremely low temperature causes ergonomic difficulties for school and hospitals. Young students and patients of hospitals are very vulnerable to extreme temperature. Drought may cause difficulties in water supply for construction sites resulting project implementation delays. Drought may cause difficulties in water supply and daily operation of project activities both in domestic and industrial zones.
Output 4. Institutional capacity of involved agencies Improved. This output does not involve any constriction or engineering work.	Facilities on project sites can be damaged during violent precipitation events and consequential floods. Extremely intense precipitation and flood can disturb regular operation and maintenance human resource arrangement, in case the project sites have access difficulties.

11. The overall review for potential climate risk is assessed as medium: The project has high climate risks of violent precipitation, flood and drought. The climate risk of low temperature and high temperature are very small. According to academic studies based on modern observation results, drought intensity and its influence increased in spring, autumn and winter while a slight downward trend exists in summer. Flood intensity and its influence generally showed a downward trend. Flood intensity and its influence in summer exhibited a slight upward trend, while other seasons showed a downward trend. The global gravity of climate risk of Yunnan Lincang Border Economic Cooperation Zone Development Project (The project) is assessed as **medium.**

12. **Linked facilities.** The project sites of Yunnan Lincang Border Economic Cooperation Zone Development Project (The project) and all linked facilities such as municipal utility facilities and transportation facilities are all dispersed in Yunnan Province. Considering that Yunnan Province is assessed as the sole target for this project, the linked facilities shall have the same climate risks as project activities. Hence, the global gravity of climate risk of associated facilities is assessed as **medium**.

13. While the Bank's Safeguard Policy Statement (SPS) requires environmental due diligence of associated facilities in adjacent areas. The project has no input into the design or operation of these associated facilities. The management units of project activities are recommended to have a communication mechanism with administration of associated facilities to coordinate climate change adaption and mitigation actions.

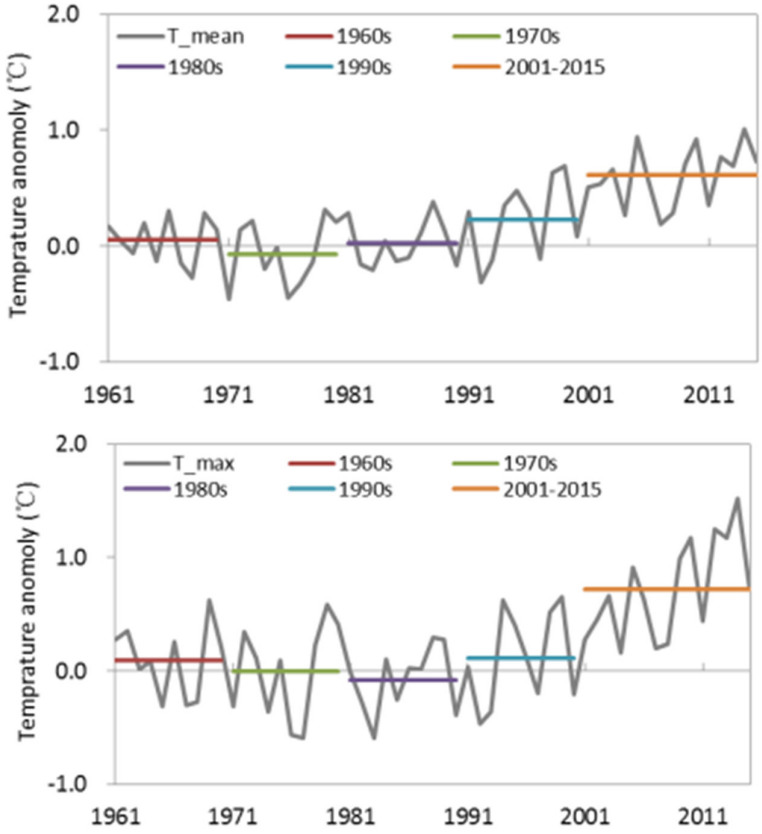
B. Climatic Trends

14. **Studies of Regional Climate Change:** Some features of the climate change and response of extreme strong rainfall events and droughts to global climate warming over

Yunnan Province have been analyzed by using temperature and rainfall data. The regional climate changing trend also has been explored respectively in the areas of Shangri- la, Xishuangbanna and Kunming. The results shows Yunnan temperature changing trend in recent 50 years behaved nearly in paralleling with the global, Northern Hemisphere and China, Yunnan temperature changing range is slightly more than the global and a little less than the Northern Hemisphere and China. The average temperature over Yunnan Province has been increasing since the late 1980s and has become most obviously warmed since the 1990s, and 13 warm winters have occurred since 1986. The number of frost days in winter and spring has gradually decreased in many areas over Yunnan. With the climate warming in recent years, the number of snow days in Shangri- la and fog days in Xishuangbanna has been decreased most obviously and the number of rain days also has decreased gradually, the change of heavy rain occurrence frequency was not obviously, but rainstorm appeared frequently, the occurrence frequency of heat wave and drought events increased. Upon entering the 21st century, the changing trend of rainfall over Yunnan has been reduced, the number of heat wave and drought events has been changed frequently and increased, and the occurrence frequency interval changed from 2- 3 years to 1- 2 years. The spring and summer continuous drought in 2005 and spring drought in 2006 were respectively most severe drought events over Yunnan Province in recent 50 and 20 years.

Observed climate change in Lincang project area

15. **Changes in annual and decadal temperature and precipitation:** The annual mean temperature increases at a warming rate with 0.15℃/10a, less than annual maximum temperature with the warming rate about 0.17℃/10a, while the warming rate is 0.27℃/10a for the annual minimum temperature, which is the highest warming rate compared with the annual mean and annual maximum temperature (Figure 3). The warming starts from 1990s and has been successively warmer than any previous decades till 2015.



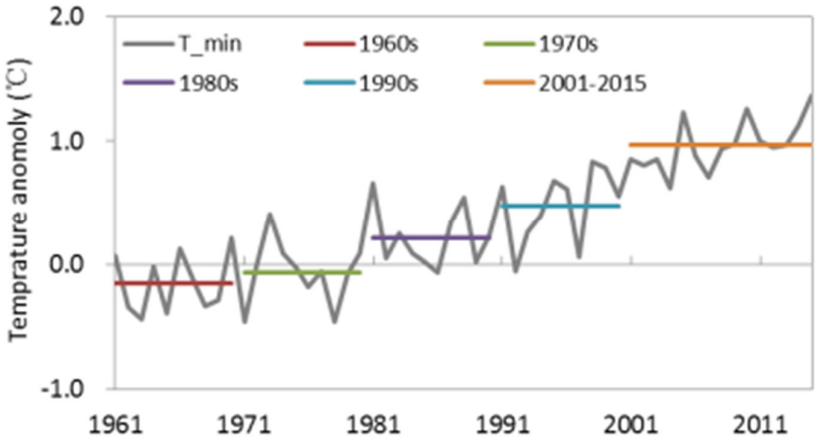


Figure 3. Changes in annual and decadal mean temperature (Tmean), maximum temperature (Tmax) and minimum temperature (Tmin) for Lincang project area for 1961-2015 (reference period: 1961-1990)

16. The average annual total precipitation fluctuates with a decreasing trend with 28mm/10a. The dry period starts from 1990s and has been successively drier than any previous period (Figure 3). There is a decreasing trend in annual rainfall day with 5.1 day/10a. The changes in decadal rainfall day shows there are consecutive three decades (1970s,1980s and 1990s) with rainfall days less than the average rainfall days from 1961-1990 (Figure 4). However, there is more rainfall and rainfall days since 2013.

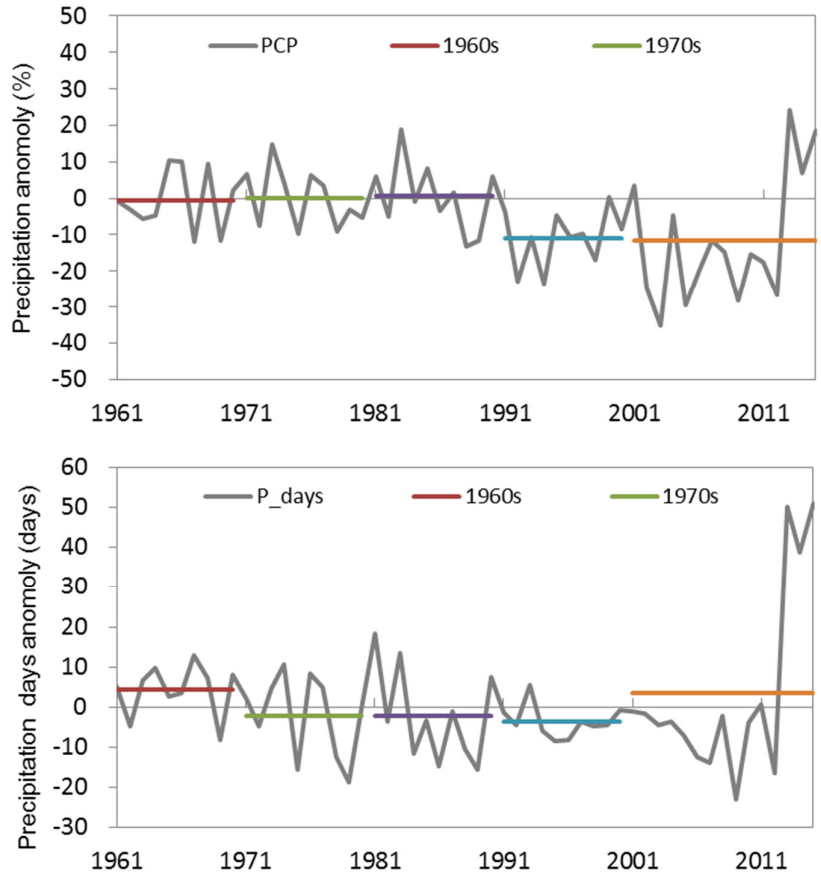


Figure 4. Changes in annual and decadal precipitation (PCP) and rainfall days (P_days) for the time period 1961-2015 for Lincang project area (reference period: 1961-1990)

17. The annual daily maximum rainfall shows slight increasing during 1961-2015. The changes in decadal annual daily maximum rainfall shows there are two period (1980s and 2001-2015) with larger annual daily maximum rainfall (Figure 5). The daily mean precipitation shows dramatically decreasing during 1961-2015 and there are consecutive decadal for 1990s and 2001-2015 with daily rainfall less than 1961-1990.The increasing in annual maximum rainfall and decreasing in daily mean rainfall imply that large rainfall will be larger, while the light rainfall will be smaller.

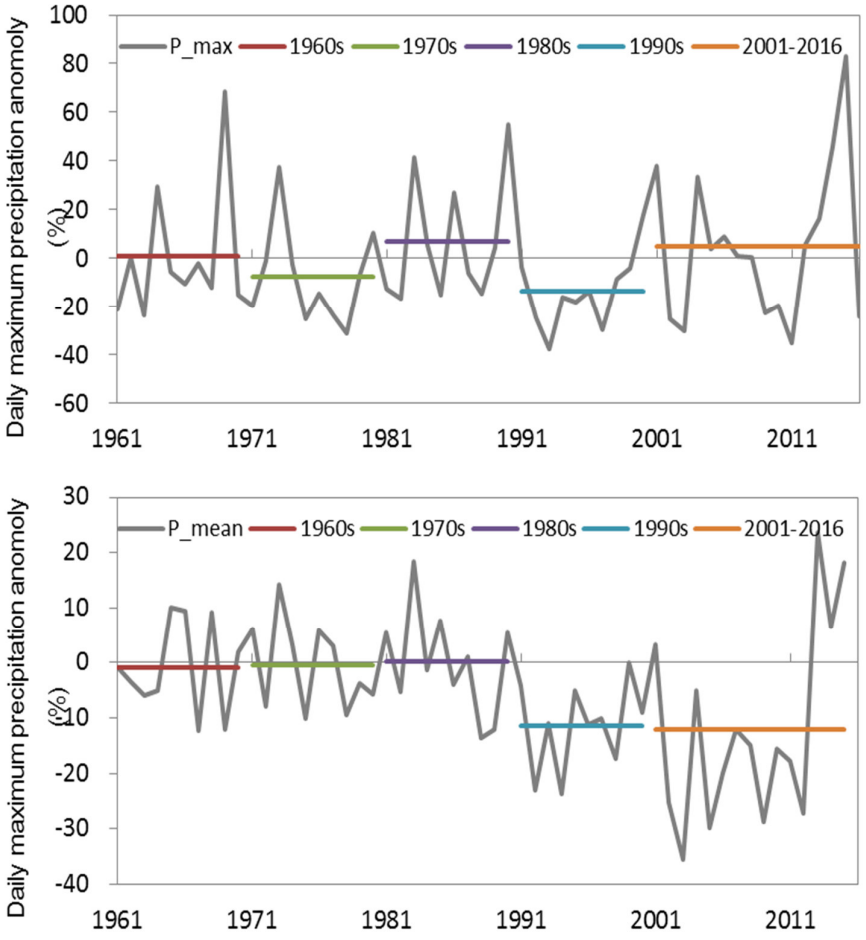


Figure 5. Changes in annual and decadal annual daily maximum rainfall (P_max) and daily mean rainfall (P_mean) for the time period 1961-2015 for Lincang project area (reference period: 1961-1990)

18. **Changes in monthly temperature and precipitation:** There are general increases in monthly temperature for each month for monthly mean, maximum and minimum temperature during 1991-2015 comparing with 1961-1990 (Figure 6). However, the monthly maximum temperature decreases in May for 1991-2015 comparing with 1961-1990. There is warmer winter compared with other seasons for 1991-2015.

19. The monthly precipitation decrease from June to December for 1991-2015 comparing with 1961-1990, while there is little changes or general increases from January to May (Figure 6).

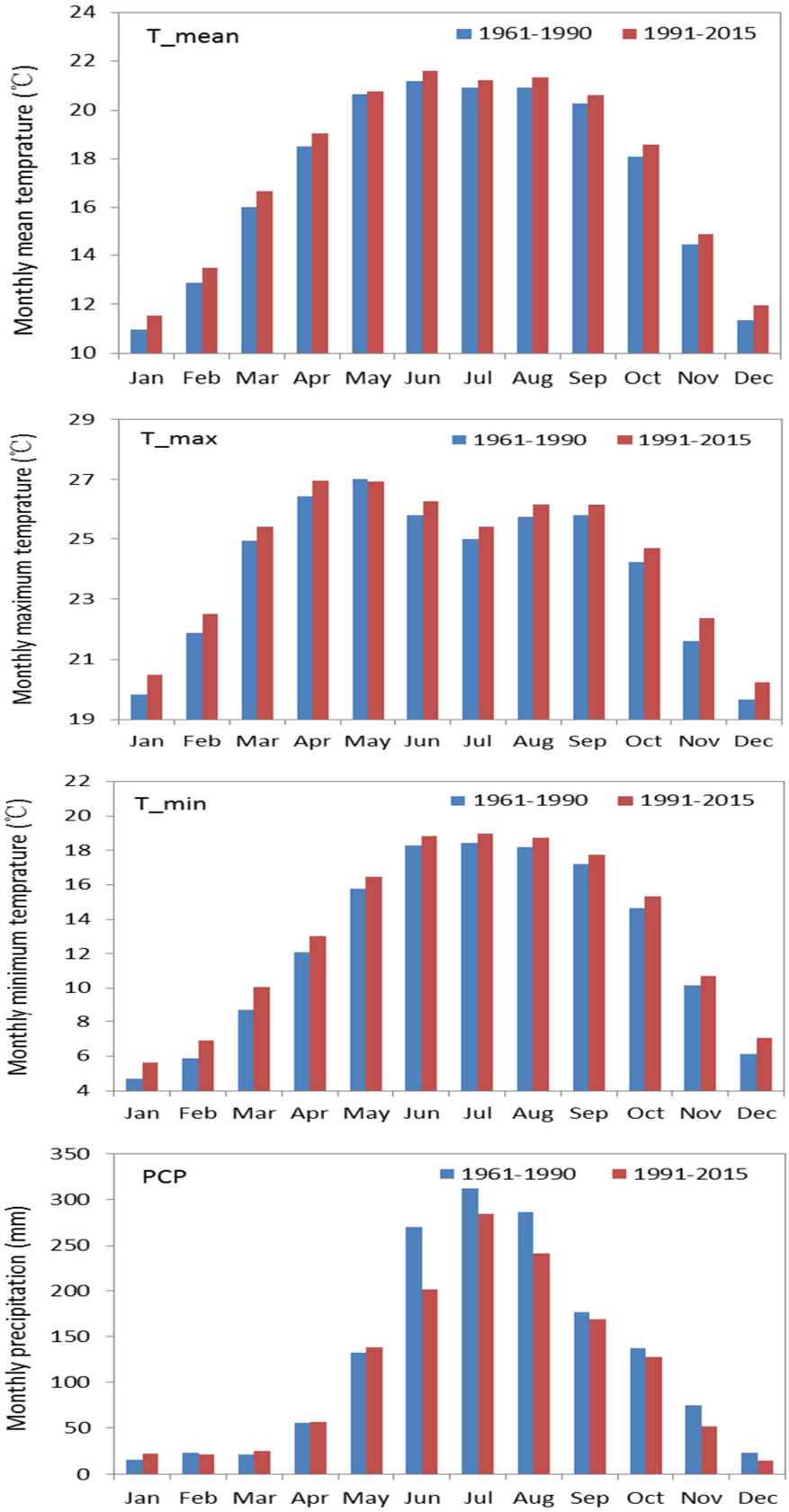
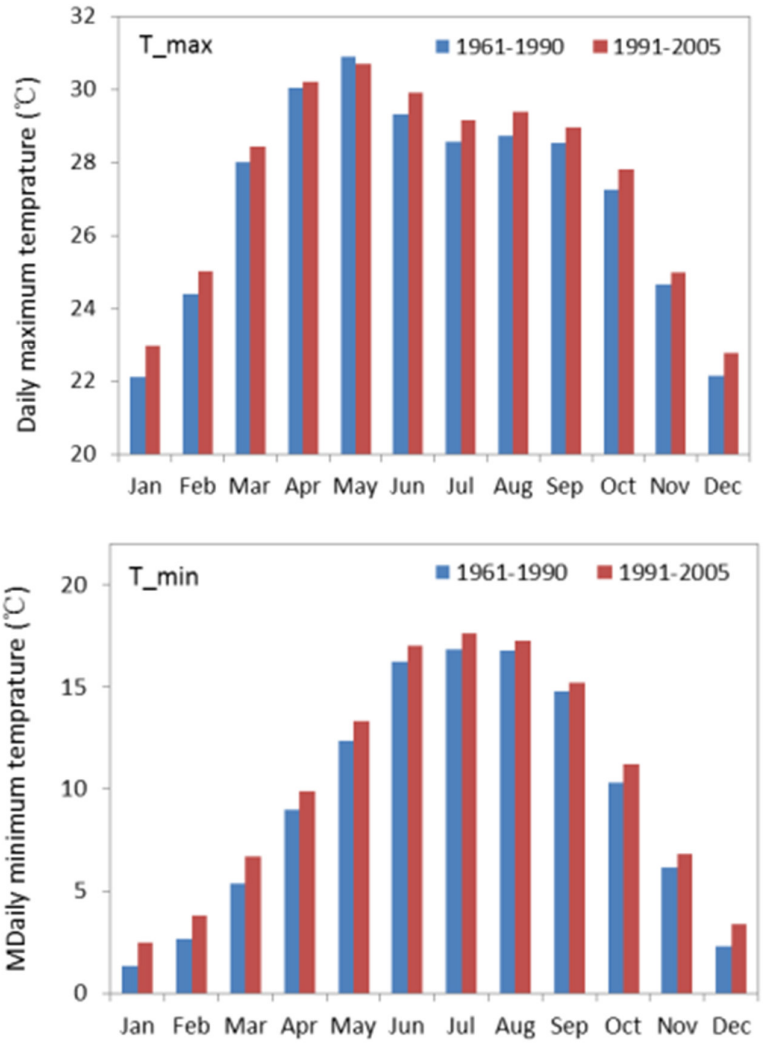


Figure 6. Monthly mean temperature (T_mean), maximum temperature (T_max) and

minimum temperature (T_min), and monthly precipitation in 1961-1990 and 1991-2015 for Lincang project area

20. **Changes in daily maximum temperature, minimum temperature and maximum precipitation in each month:** Both the average daily maximum and minimum temperature have increased in 1991-2015 comparing with 1961-1990 except that there is decrease in daily maximum temperature in May for 1991-2015. The result shows that the decrease in average daily maximum temperature is consistent with the decrease in monthly maximum temperature in May for 1991-2015 comparing with 1961-1990 (Figure 6).

21. The average daily maximum precipitation has decreased in February and from June to December while has increased in January and from March to May in 1991-2015 comparing with 1961-1990 (Figure 7).



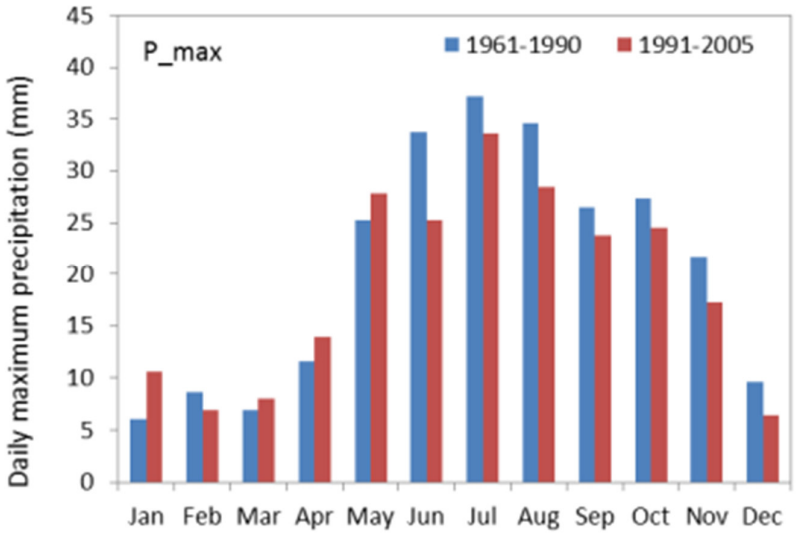


Figure 7. Daily maximum (T_max) and minimum temperature (T_min) and maximum precipitation (P_max) in each month in 1961-1990 and 1991-2015 for Lincang project area

Summary for observed climate change

22. In Lincang project area the average annual temperature has increased during 1961-2015 characterized with warmer winter. The annual total precipitation is fluctuated featured a slight decreasing trend, with decreasing in annual rainfall days. However the intensive extreme storm has increased which implies large rainfall will be larger, while the light rainfall will be smaller. The changes monthly precipitation shows drier summer and autumn. Furthermore, the average daily maximum rainfall also decreases in summer and autumn. The warming combined with decreases in precipitation will cause more frequent and intense seasonal and periodic droughts.

Projected climate change in Lincang project area

23. **Changes in annual temperature and precipitation:** In Lincang project area, projected changes of annual mean temperature under RCP4.5 and RCP8.5 scenarios for the 2015–2099 show that there will be substantial warming in the future. The increasing trend for 2015-2099 will be higher than observed warming trend for 1961-2015 with about 0.39℃/10a for annual mean temperature, 0.42℃/10a for annual maximum temperature and 0.37℃/10a for annual minimum temperature under RCP8.5. The increasing trend will be smaller than observed warming trend for 1961-2015 with about 0.11℃/10a for annual mean temperature, 0.10 ℃ /10a for annual maximum temperature and 0.14 ℃ /10a for annual minimum temperature under RCP8.5. In general, greater temperature rises for the late 21st century, and greater values under RCP8.5 compared to RCP4.5 are found. As shown in the figure, warming follows a similar magnitude prior to 2050 under RCP4.5 and RCP8.5, indicating that the warming is less scenario dependent in the first half of the 21st century. In later half, however, the temperature continues to rise almost linearly under the RCP8.5 scenario, while quasi stabilization is found for RCP4.5.

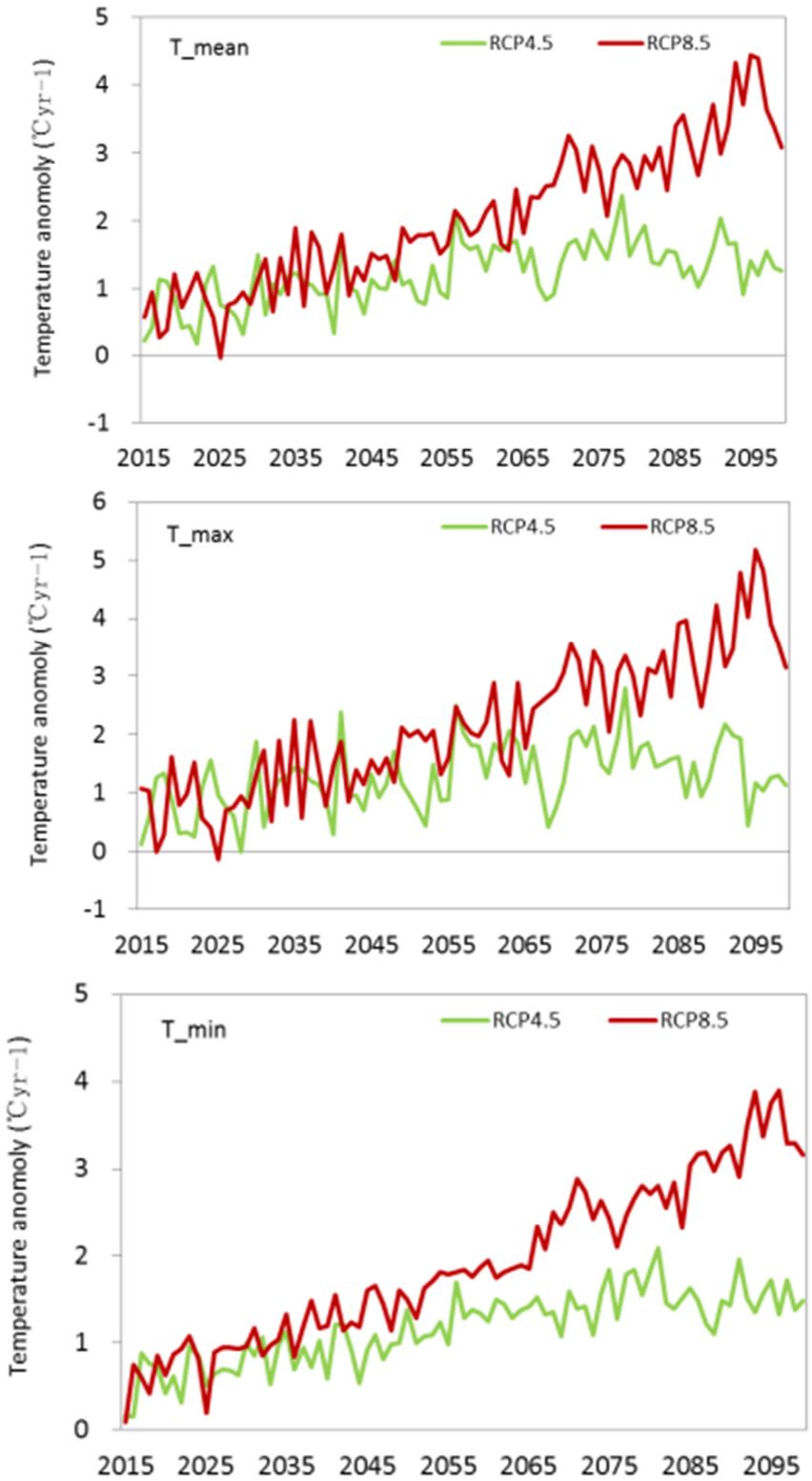


Figure 8. Projected changes in annual mean (T_mean), annual maximum (T_max) and annual minimum (T_min) temperature for 2015-2099 under RCP4.5 and RCP8.5 for Lincang project area (baseline: 1986-2005, unit: ℃)

24. In Lincang project area, there is increasing trend under RCP4.5, and no clear trend

under RCP8.5 for annual precipitation toward the end of the century.

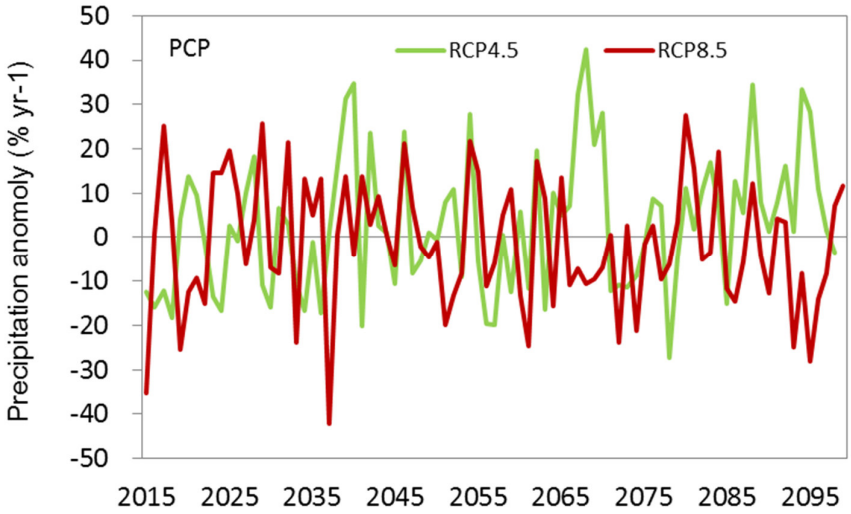


Figure 9. Projected changes in annual precipitation for 2015-2099 under RCP4.5 and RCP8.5 for Lincang project area (baseline: 1986-2005, unit: %)

25. In Lincang project area, the projected decadal temperature will be reached highest level at 2070s, with the warming about larger 1.7℃, 1.8℃, and 1.5℃ for decadal mean, maximum and minimum temperature respectively under RCP 4.5. While the highest warming level at the end of 21th century under RCP8.5, with the warming about larger 3.7℃, 4.0℃, and 3.4℃ for decadal mean, maximum and minimum temperature respectively (**Error! Reference source not found.**3). As shown in **Error! Reference source not found.**3, the projected decadal precipitation changes for Lincang project area show an opposite condition under RCP4.5 and RCP8.5 for 2020s, 2030s, 2060s and 2090s.

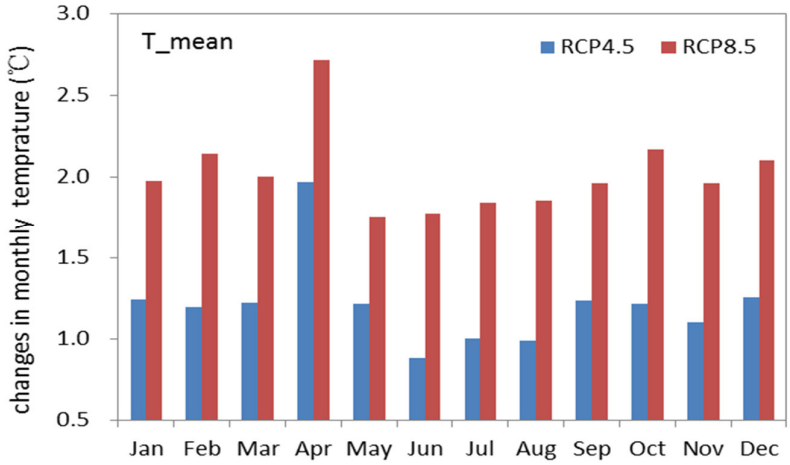
Tab.03 – Projected Changes in Decadal Temperature and Precipitation for Lincang project area (baseline: 1986-2005)

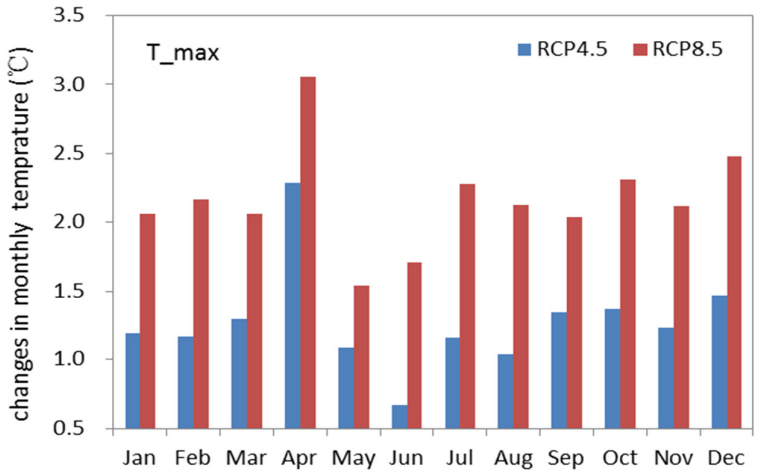
Decade	Tmean(℃)		Tmax(℃)		Tmin(℃)		PCP (%)	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
2020s	0.8	0.8	0.8	0.8	0.7	0.9	-2	5
2030s	0.9	1.3	1.0	1.4	0.9	1.1	5	-1
2040s	1.1	1.4	1.2	1.5	1.0	1.4	1	4
2050s	1.3	1.8	1.4	2.0	1.2	1.7	-1	-2
2060s	1.5	2.4	1.5	2.6	1.4	2.3	6	-5
2070s	1.7	2.8	1.8	3.0	1.5	2.6	-3	-6
2080s	1.4	3.0	1.4	3.1	1.5	2.9	9	3
2090s	1.5	3.7	1.4	4.0	1.5	3.4	11	-7

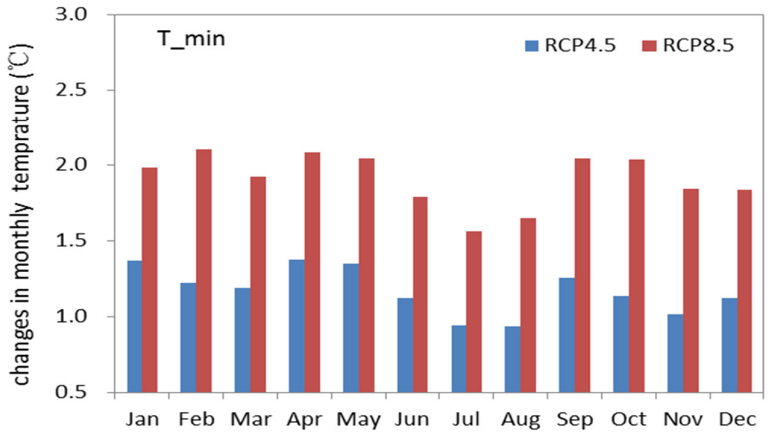
26. **Projected changes in monthly mean temperature and precipitation:** In Lincang project area, projected monthly temperature will increase consistently in the future period 2021-2050 under RCP4.5 and RCP8.5 for mean temperature (ranges from 0.9℃ to 2.0℃ under RCP4.5, and 1.8℃ to 2.7℃ under RCP8.5), maximum temperature (ranges from 0.7℃ to 2.3℃ under RCP4.5, and 1.5℃ to 3.1℃ under RCP8.5) and minimum temperatures (ranges from 0.9℃ to 1.4℃ under RCP4.5, and 1.6℃ to 1.1℃ under RCP8.5). The temperature rises in April under RCP4.5 and RCP8.5 will substantial higher than warming in other months (Figure 10).

27. **There** is no clear shift of peak rainfall season. Generally, there are consistent changes

in projected precipitation in the most months except in July and November under RCP4.5 and RCP8.5. There are greater and consistent increase in monthly precipitation projected in February, May, June and September (1~22% under RCP4.5, 11~16% under RCP8.5). There are consistent decrease in monthly precipitation in January, March, April, August, October, and December which less rainfall projected under RCP8.5 (-1~-21% under RCP4.5, -3~33% under RCP8.5).







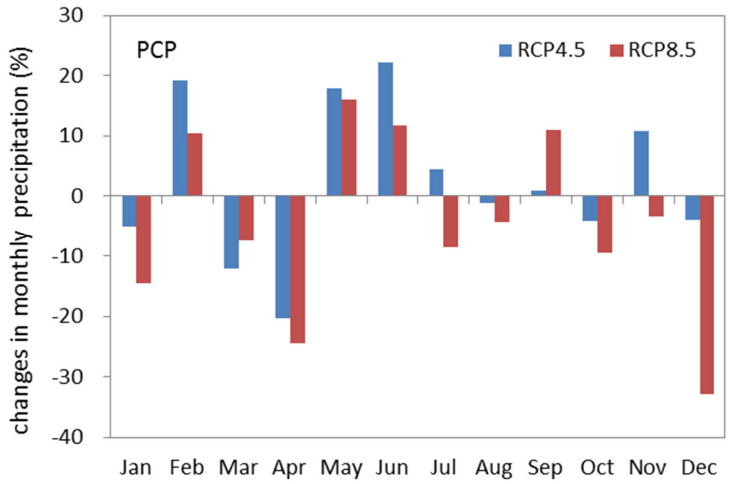
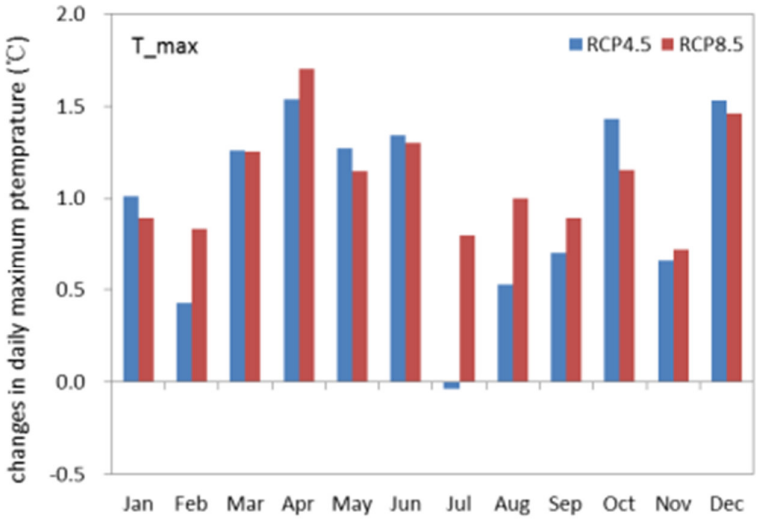


Figure 10. Projected changes in monthly mean, maximum and minimum temperature, and monthly precipitation for 2021-2050 under RCP4.5and RCP8.5 for Lincang project area (baseline: 1986-2005, unit:℃)

28. **Projected changes in daily maximum and minimum temperature and maximum precipitation in each month.** In Lincang project area, it is projected that mean maximum daily temperature will increase for all months of the year except in July under RCP4.5 with the magnitude ranges from 0.0℃to 1.5℃ under RCP4.5, and 0.7℃ to 1.7℃ under RCP8.5. The projected mean minimum daily temperature will increase for all months of the year with the magnitude ranges from 0.3℃ to 1.5 ℃ under RCP4.5, and 1.0℃ to 1.6°C for RCP8.5.



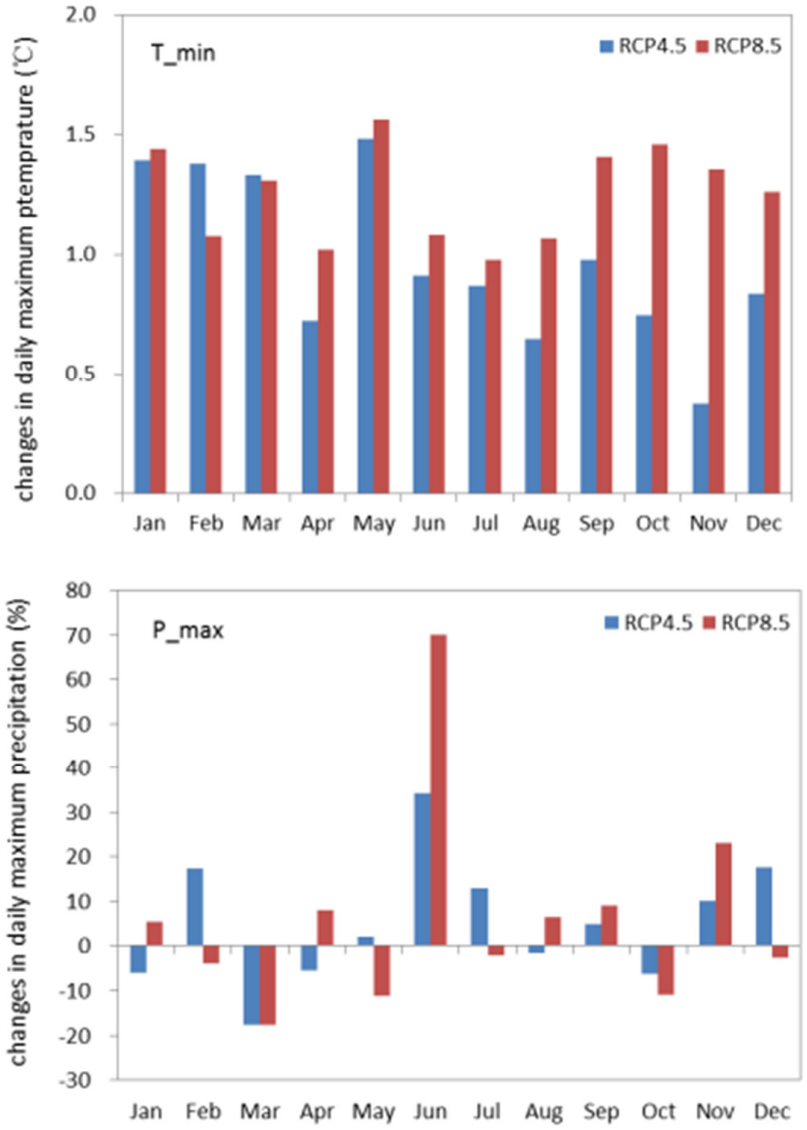


Figure 11. Projected changes in daily maximum and minimum temperature and maximum precipitation in each month for 2021-2050 under RCP4.5and RCP8.5 for Lincang project area (baseline:1986-2005, unit:℃)

Summary for projected climate change

29. The annual temperature is projected to continue to increase to the end of 21th century. However the probability of heat wave and cold events will be low before 2050. Annual rainfall is projected to increase slightly under RCP4.5 and no clear trend under RCP8.5 toward the end of the century. More months with decreased monthly precipitation is projected, while the projected changes in average daily maximum precipitation with less consistent under RCP4.5 and RCP8.5. The projected consistently increases in average daily maximum precipitation in June will to be increase the flood. The projected decreases of monthly precipitation, increases of monthly temperature will to be cause seasonal or periodic drought.

C. Review of Literature concerning climatic change

Tab 04. Literature reviewed

No.	Document	General contents	Implications for the Project
1	Economic analysis of climate-proofing investment projects By Asian Development Bank	ADB's climate risk management framework	ADB's climate risk management framework
2	Climate Risk Management in ADB Project By Asian Development Bank	ADB's climate risk management framework	ADB's climate risk management framework
3	ADB Climate-Related Disasters in Asia and the Pacific	Disaster Risk and Climate Change, Extreme Temperatures and Precipitation, Hazards, Exposure, Vulnerability	Risks concerning buildings and infrastructure
4	World Bank Climate Trends and Impacts in China	Climate Trends and Impacts in China	Climate Trends and Impacts in South China
5	Statistical Downscaling and Projection of Future Air Temperature Changes in Yunnan Province, China By Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (CAS)	Climate data generated by five general circulation models (GCMs) Outputs of scenarios (Representative Concentration Pathways) RCP2.6, RCP4.5, and RCP8.5 of the third-generation Coupled Global Climate Model (CGCM3) from the Meteorological Research Institute of Japan (MRI) were from 2006 to 2100.	General circulation models (GCMs) for Yunnan Province
6	Dry'-Wet Climate Change in Yunnan During 1961—2010 By Department of Observation and Network and Yunnan Provincial Meteorological Administration	Historical weather records of Yunnan Province	Historical weather records of Yunnan Province
7	Climate Change Features in Yunnan from 1961 to 2010 By: Yuxi Agriculture Vocation-Technical College	Historical weather records of Yunnan Province	Historical weather records of Yunnan Province
8	Characteristics of Droughts and Floods Analyzed Using the Standardized Precipitation	Climate trend analysis of Yunnan Province	Climate trend analysis of Yunnan

No.	Document	General contents	Implications for the Project
	Index in Yunnan Province During the Past 55 Years By: College of Water Sciences, Key Laboratory for Water and Sediment Sciences of Ministry of Education, Beijing Normal University		Province
9	CDM Project Description Document: Mitigation of GHG: Rubber based agro-forestry system for sustainable development and poverty reduction in Pakkading, Bolikhamsay Province, Lao PDR By: UNFCCC, CDM development consultant	Baseline and project activity carbon emission computation methodology and experiential emission values	Baseline and project activity carbon emission computation methodology and experiential emission values

II. Assessing adaptation needs

30. The adaptation measures appropriate to the project are derived in a three-step process namely: impact, vulnerability and adaptation analyses.

31. Impact assessments consider climate trends and climate predictions. The vulnerability assessment considers the degree to which climate change impacts could adversely affect the objectives of the irrigation subprojects. The assessment of adaptation in design and operation considers engineering and non-engineering solutions. Finally, the implementation of adaptation measures is described.

A. Impact Assessment

32. **Impact of flooding on public service facility (Schools and Hospitals etc):** Flooding can cause site erosion, structural and nonstructural building damage, the destruction or impairment of utilities and mechanical equipment, damage to or loss of contents, health threats from contaminated floodwater, and temporary or permanent closure. The eventual damages could be: **Site damage.** Building grounds may be subject to erosion and scour, with the possible loss of soil and damage to paved areas, including access roads. Large amounts of debris and sediment can accumulate on the site, especially against fences. **Structural damage.** Foundations can be eroded, destabilizing or collapsing walls and heaving floors. **Saturation damage.** Saturated walls and floors can lead to plaster, drywall, insulation, and tile damage, mold and moisture problems, wood decay, and metal corrosion. **Utility system damage.** Electrical wiring and equipment can be shorted and their metal components corrode. Ductwork can be fouled and expensive heating and cooling equipment ruined. Oil storage tanks can be displaced and leak, polluting the areas around them. Sewers can back up and contaminate the water supply and building components. **Contents damage.** School furniture, computers, files, books, lab materials and equipment, and kitchen goods and equipment can be damaged or contaminated. **Health threats.** Mold growth and contaminants in flooded schools can pose significant health threats to students and staff. **School closure.** Flooded schools must be closed during cleanup and repair. The length of closure and the ability of the school district to return to teaching depend on the severity of the damage and lingering health

hazards. It may also depend on whether the school is fully insured or how quickly disaster assistance is made available for cleaning and repair. If the school is located in a flood plain, it may be permanently closed. **Hospital Evacuation.** Hospitals are very vulnerable to floods. Patients and medical equipment can be damaged with intensive flushing or flooding.

Figure 12: A flooded hospital

33. **Impact of flooding on transportation and ergonomic:** Often flooding is a complex combination of various causes (coastal, fluvial and pluvial). Further, transportation systems are very sensitive to external disturbances. Transportation systems are usually paralyzed in Hunan province during flood period. Traffic on inundated roads will be interrupted or delayed according to the manner of flood propagation. As a consequence, some trips will be cancelled or rerouted and other trips will be indirectly affected. During floorings, equipment and facilities in the project sites such as leachate treatment plant, MSW transfer stations, will lose most part of efficiency due to mechanic and ergonomic problems.

Figure 13: A flooded highway

34. **Impact of drought on domestic and industrial zones:** Drought can have serious health, social, economic and political impacts with far-reaching consequences. Water is one of the most essential commodities for human survival, second only to breathable air. So when there is a drought, which by definition means having too little water to meet current demands, conditions can become difficult or dangerous very quickly. Drought may cause difficulties in water supply for construction sites resulting project implementation delays. Drought may cause difficulties in water supply and daily operation of project activities both in domestic and industrial zones.

B. Vulnerability Assessment

1. Cross-border capacity improved.

35. **Design.** Construction sites are highly vulnerable to floods and violent precipitation events. The design of construction deployment must consider emergent drainage. The project sites should be designed with water deviation/interception trench and other anti-flood structures. The design of construction sites must consider emergent drainage. During drought period, the water supply to construction site should be secured.

36. On both domestic and industrial activity sites, precipitation water shall be introduced into well-defined interception structures and collected into large capacity drainage channels. In extreme cases, the site can be flooded. Emergent pumping system shall be available on both domestic and industrial activity zones.

37. Project sites constructed in lower positions shall be equipped with escaping facilities for human evacuation during eventual flooding events.

38. Drainage well orifices shall be designed with anti-overflow measurement.

39. Extreme low temperature call cause water pipeline bursts. Temperature protection measurement shall be available. **(very minor risk)**

40. **Materials, maintenance and performance**.

41. After flooding events, maintenance and reparation plan must be implemented to avoid further pollutant release and building/road structure raptures.

2. Integrated urban environmental infrastructures in Qingshuihe border area Improved.

42. **Design.** Construction sites are highly vulnerable to floods and violent precipitation events. The design of construction deployment must consider emergent drainage. Waste collection and treatment sites should be designed with water deviation/interception trench and other anti-flood structures. .

43. Water treatment facilities and waste treatment facilities shall be equipped with escaping facilities for human evacuation during eventual flooding events.

44. An emergency reaction plan shall be available to evacuate human and equipment during flooding events.

45. **Materials, maintenance and performance**. The project shall choose construction equipment and other materials with tolerance to water erosion. On operational sits, emergency reaction plans shall be available to evacuate human and equipment during flooding events.

46. Water pipes and wastewater pipes should be resilient against low temperature without frequent severe bursts.

3. Social infrastructure and service improved.

47. **Design.** The location of schools and hospitals shall be chosen with less risks of flooding.

48. Construction sites are highly vulnerable to floods and violent precipitation events. The design of construction deployment must consider emergent drainage. The project sites should be designed with water deviation/interception trench and other anti-flood structures. Drainage well orifices shall be designed with anti-overflow measurement.

49. During drought period, the water supply to construction site should be secured.

50. Underground floors of schools and hospitals shall be equipped with reasonable safe house or other escaping facilities for human evacuation during eventual flooding events.

51. Potable water supply shall be secured with action plan and backup facilities and materials during drought period.

52. **Materials, maintenance and performance**. The project shall choose materials and equipment with tolerance to water erosion.

53. An emergency reaction plan shall be available to evacuate human and equipment during flooding events.

4. Institutional capacity of involved agencies Improved.

54. **Design.** Avoid flooding locations.

55. Potable water supply shall be secured with action plan and backup facilities and materials during drought period.

C. Adaptation Analysis and Measures

56. During construction period, anti-flotation and anchoring measurement shall be available to antagonize flood. The building, any gas or liquid storage tanks, and any equipment servicing the building must be designed and anchored to prevent flotation, collapse, or lateral movement during the 100-year flood event. In addition to anchoring the building to its foundation, it is necessary to ensure that the foundation won't move (due to hydrostatic forces, hydrodynamic forces, or undercutting by erosion or scour). In areas where flood velocities exceed five feet per second, additional anchoring measures may be required, such as reinforcing crawlspace walls, using deeper footings, using extra bolts to connect the sill to the foundation, or installing rods to connect the cap to the sill.

57. For operational purpose, possible climate proofing measures for this project mainly focus on design features, but also include recommendations for materials, maintenance and performance. Designs of the proposed project components are required to take into account the climate change impact on seasonal runoff/flash floods, increased temperature effects and severe weather events. The measures relating to materials, maintenance, and performance focus on stipulation of high quality improving the relevant government policy and institutional capacity to implement the designs and properly maintain the facilities.

1. Design and Performance strategies

58. A list of design and performance strategies which address the vulnerabilities identified in this CRVA, by component sectors is provided in Table 05 below. During project preparation, and later in the detailed design phase of project implementation these recommendations should be included in final specifications for construction.

59. Some of the project components will be integrated into the entire surrounding habitation area. Mitigation and adaptation measurements shall be implemented with coordination of the adjacent habitation area. Associated facilities such as water supply

pipelines and electricity distribution grid shall receive appropriate maintenance organized by the municipal administration comply with national standard and ADB climate change policy.

Tab 05: Adaptation/Resilience Measures

Component sector	Adaptation/Resilience Measures
Qingshuihe Border Trade Facilities construction and road paving in the border zone.	▪ Design of building structure, should be to pass a 1-in-100-year flood, plus a standard safety margin, plus a 6% margin for flash flood peaks. ▪ Surface water-shedding drainage should be designed for a 1-in-5-year rainfall event. ▪ Water pipes and leachate pipes should be resilient against low temperature without frequent severe bursts. ▪ Materials and equipment should have enough resilience with margin against 10 days water scouring or soaking. ▪ Landscape sites and eventual compensation reforestation shall have emergency irrigation system to antagonize drought.
Potable water supply system, wastewater treatment facilities, municipal waste treatment system, River rehabilitation and new energy connecting points.	▪ Project sites shall be equipped with escaping facilities for human evacuation during eventual flooding events. ▪ Design of building structure, should be to pass a 1-in-100-year flood, plus a standard safety margin, plus a 6% margin for flash flood peaks. ▪ An emergency reaction plan shall be available to evacuate human and equipment during flooding events. ▪ Ground surface water-shedding drainage should be designed for a 1-in-5-year rainfall event. ▪ Materials and equipment should have enough resilience with margin against 10 days water scouring or soaking. ▪ Water pipes and leachate pipes should be resilient against low temperature without frequent severe bursts. ▪ Landscape sites and eventual compensation reforestation shall have emergency irrigation system to antagonize drought.

Construction of schools and hospitals	▪ Design of facilities and buildings, should be to pass a 1-in-100-year flood, plus a standard safety margin, plus a 6% margin for flash flood peaks. ▪ Surface water-shedding drainage should be designed for a 1-in-5-year rainfall event. ▪ Water pipes and leachate pipes should be resilient against low temperature without frequent severe bursts. ▪ Materials and equipment should have enough resilience with margin against 10 days water scouring or soaking. ▪ Water pipes and leachate pipes should be resilient against low temperature without frequent severe bursts. ▪ Landscape sites and eventual compensation reforestation shall have emergency irrigation system to antagonize drought.
Institutional capacity of involved agencies Improved. This output does not involve any constriction or engineering work	▪ Project sites shall be equipped with escaping facilities for human evacuation during eventual flooding events. ▪ An emergency reaction plan shall be available to evacuate human and equipment during flooding events.

2. Non-engineering measures

60. Non-engineering approaches focus on the facilities and associated facilities shared with adjacent areas. Governing municipal government of each project site should use administrative measurements to guarantee the water supply network and electricity distribution grid are robust enough to be operational during extreme climate events.

61. Environment Protection Bureau is the governing office for some of the associated facilities, Governing municipal government of each project site shall liaise with EPB for coordination on climate mitigation and climate adaptation works.

62. **GHG reduction of project activities:** A computation of GHG emission of project baseline scenario (without project) and GHG emission of project scenario (with project) has been conducted by climate change expert. The detail computation methodologies and equations are available in a separate calculation sheet. The computation results are listed as following:

- Deforestation: = **23,027 $eTCO_2$** Carbon sink loss
- Facilities of wastewater treatment = **- 31,990 $eTCO_2$** Emission Reduction
- Transportation = **- 23,999 $eTCO_2$** Emission Reduction
- Waste treatment = **- 3,403 $eTCO_2$** Emission Reduction
- Building construction = **72,255 $eTCO_2$ Emission**

Annual Carbon Emission Balance: 35,890 eTCO2 Emission Increase

ANNEX A:

Advances in the Research of Yunnan's Arid Climate and Extreme Drought

ABSTRACT

With the global climate change, the extreme drought was increasing. From 2009 autumn to 2010 spring, a hundred-year drought happened in Yunnan province, which caused great local economic losses and widespread attention. So many researches about Yunnan drought were studied. The climatic characteristics of the drought over Yunnan are studied by analyzing the spatial and temporal distribution of some meteorological factors such as precipitation, temperature and sunlight, etc. Some researchers studied the formation mechanism of the drought events in Yunnan. In this paper, by investigating lots of related documents, we had a summarization and commentary about the recent study achievements of Yunnan drought and tried to offer reference to the study on the Yunnan drought in the future.

KEYWORDS

Yunnan, Arid Climate, Extreme Drought, The Atmospheric Circulation, Change Characteristic

1. Introduction

Yunnan is situated in the low-latitude plateau with complex geography and climate. Yunnan has very distinctive dry and wet seasons. It is generally thought that the rainy season is May-October, and dry season ranges from November to the next April (up to half year). According to the climatic data statistics, in the Yunnan region, the precipitation in the dry season accounts for 16% of the precipitation in the whole year, and the average daily precipitation during this period (average level throughout Yunnan Province) is only 0.93 mm (which is far lower than the evaporation in the same period). Therefore, drought is frequent in Yunnan, and there is the saying that “there is drought in nine of ten years”. Yunnan is the province with the severest drought in southwest China region and is also one of the regions with frequent drought in China. Under the context of global warming, the extreme weather and climatic hazard events have been constantly aggravated, and the extreme drought events once in a hundred years or in dozens of years happen frequently. Compared with other natural hazards, drought is characterized by high frequency, long duration and wide scope of influence, thus having huge impact on the national economy, particularly the agricultural production. In 2009/2010, super-severe drought happened in Yunnan and Guizhou, and the duration of drought in Yunnan indicated the super-severe drought in the local place since there was the meteorological record. This extreme drought event had wide scope of influence, and till May 31, 2010, 25.12 million persons in Yunnan Province suffered hazards, in which 7.57 million persons had the difficulty in obtaining the drinking water; the drought also caused the agricultural crops of 2.174 million Hectare to be affected in the autumn and winter, and direct economic loss over RMB 20 billion. This has aroused high emphasis of the government and meteorological scholars, and the related research work has been deeply carried out. The authors combed these research results, to provide the reference for subsequent study of drought.

2. Climatic Change Characteristics in Yunnan

The disaster-resulting factor of drought hazard is the meteorological factor, which mainly depends on the precipitation, atmospheric temperature and evaporation in a region. But with the aggravation of globalization and climatic warming, the meteorological change response in different regions was different.

2.1. The Change Characteristic of Temperature in Yunnan

In recent one hundred years, the average temperature-time trend has shown that, except the decrease of −0.092˚C/10a in Dali City, other regions is the increasing trend, Puer City in the south of Yunnan Province has the largest growth amplitude, that is, 0.105˚C/10a, which is followed by Shangri-La in the northwest of Yunnan, that is, 0.079˚C/10a. Before the 1980s, Puer City and Shangri-La were in the relatively cold period, and since the 1990s, the temperature has grown rapidly.

From the average growth amplitude of atmospheric temperature in Yunnan Province from 1961-2007, as show in Figure A1, it may be seen that in middle Yunnan, south Yunnan, southwest Yunnan, northwest Yunnan and southwest of west Yunnan, the temperature rises above 1.18˚C, and up to 2.08˚C in Kunming. In addition, the growth amplitude is obviously higher than the average national level of 1.1˚C calculated by Ding Yihui et al. In Dali and Lijiang of middle Yunnan and west Yunnan,

the temperature rises slowly and is 0.4˚C - 0.91˚C, which is lower than the average national level. In addition, in some regions of east Yunnan, northeast Yunnan, south Yunnan, middle Yunnan and west Yunnan, the annual reduction amplitude happened with 39.3 - 198.1 mm, mostly in northeast Yunnan; while in some regions of northwest Yunnan, southeast Yunnan and southwest Yunnan, the precipitation growth amplitude was 16.7 - 133.8 mm, and the regions with the largest growth amplitude happened in Tengchong in southwest of west Yunnan and northwest Yunnan region. Due to complex topography in Yunnan Province, it is largely influenced by the monsoon; there are quite different climatic regions, and the atmospheric temperature and precipitation in the regions

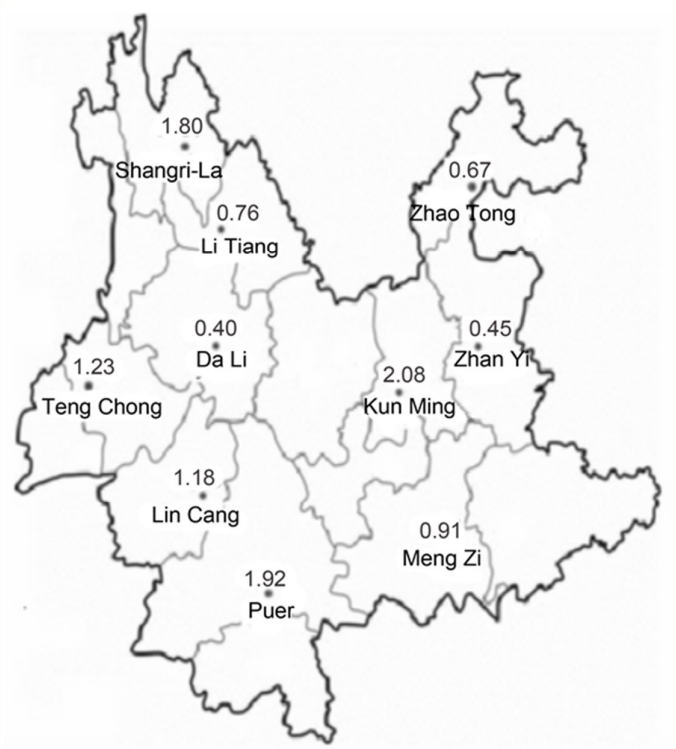


Figure A1. (Select from literature 4). The amplitude of annual average temperature for 47 years in Yunnan has different change trends in different seasons.

The temperature warming trend is related to the diurnal range of atmospheric temperature in different climatic belts in Yunnan. The growth rate of minimum atmospheric temperature bigger than that of maximum atmospheric temperature in north Asian tropic, central Asian tropic and south Asian tropic stations, so the diurnal range of temperature obviously decreases. But the change of the diurnal range of temperature in the temperate zone and north tropic zone isn't significant. The distribution of maximum atmospheric temperature in Yunnan region generally increases with the decrease of the latitude from northwest Yunnan to south Yunnan, with the change amplitude in 11.5˚C - 30.7˚C. And it also manifests obvious regional difference, such as in the south of Yunnan, dry-hot valley basin (mainly including Jinsha River, Lancang River, Yuanjiang River and Nujiang River etc.), and center of Yunnan, there is the high temperature center, and the maximum temperature center is situated in Yuanjiang River in the Yuanjiang River Basin valley region, with the temperature of 30.6˚C. Except the complex landform, that is, the "channel-obstruction" effect of the landform, the space distribution of the maximum atmospheric temperature is influenced by the altitude of the observation station. In Yunnan Province, the average change trend of annual

maximum atmospheric temperature has the obvious rise trend, with the rise rate of 0.17˚C/10a. In the inter-annual change, the extremely low value of the maximum atmospheric temperature (22.3˚C) happened in 1976, but the extremely high value (24.2˚C) happened in 2010, and the super-severe drought once in hundred years happened in the same year.

2.2. The Change Characteristic of Precipitation in Yunnan

The objective analysis of fine grate is made with the atmospheric temperature and precipitation information in 124 stations in Yunnan Province in 1961-2008 (the temperature interpolation considers the topographic height correction), and on this basis, the atmospheric temperature and precipitation sequence has received the space correction and climatic zoning. In recent 50 years, the atmospheric temperature rose most in the winter in Yunnan, then in autumn, summer and spring, but there is the falling trend in some low-altitude valley area. Average annual change of precipitation isn't large, the precipitation in the rainy season decreases, and the precipitation in the dry season rises. Liu Yu et al. drew the conclusion that the precipitation in the summer in 1961-2007 obviously decreased by analysis with the linear trend method, with the decrease rate of 4.5 mm/10a, and the sudden change of the precipitation from rise to fall had been happened about in 1971; the growth rate of atmospheric temperature in the winter was 0.27˚C/10a, and there was a sudden change from cold to warm in 1995. Regarding the regional distribution characteristics of precipitation throughout Yunnan Province, the uniform decrease happened in the summer, the precipitation decreased in the southwest Yunnan and increased in other regions in the winter, the uniform increase happened in the spring, and the precipitation in the west increased and decreased in the east in the autumn.

2.3. Change Characteristic of Evaporation Capacity in Yunnan

Solar radiation is the main factor influencing the change of evaporation, the sunshine hours can express the main constitution of solar radiation energy in one position to certain extent (that is, direct solar radiation quantity), is the energy source for the ground surface, water surface and air, and is often in positive correlation with the average temperature and ground temperature, as show in Figure A2. In Yunnan Province, the distribution of sunshine hours is generally characterized by much in west Yunnan, little in east Yunnan and more in the south than that in the north, and the maximum center mainly happens in the valley zone of Jinsha River Basin. The difference of the maximum and minimum values of the sunshine hours in Yunnan is about 1600 h. Since 1961, the change of annual sunshine hours in Yunnan is characterized by decrease in the north and increase in the south, basically taking Ailao Mountain as the boundary, with the growth trend in the west and south of Ailao Mountain, and decrease trend in the north and east of Ailao Mountain.

3. Change Characteristics of Arid climate in Yunnan

Drought is the phenomenon of water deficiency due to unbalance of water moisture budget or supply-demand. In the natural disasters in China, drought is always one of the severest disasters. At present, there are many indexes for the analysis and study of drought, and new indexes come out one after another. The causes are mainly closely related to the regional difference of the weather and climates and the complexity of drought problems. Meteorological drought indexes mainly include precipitation anomaly

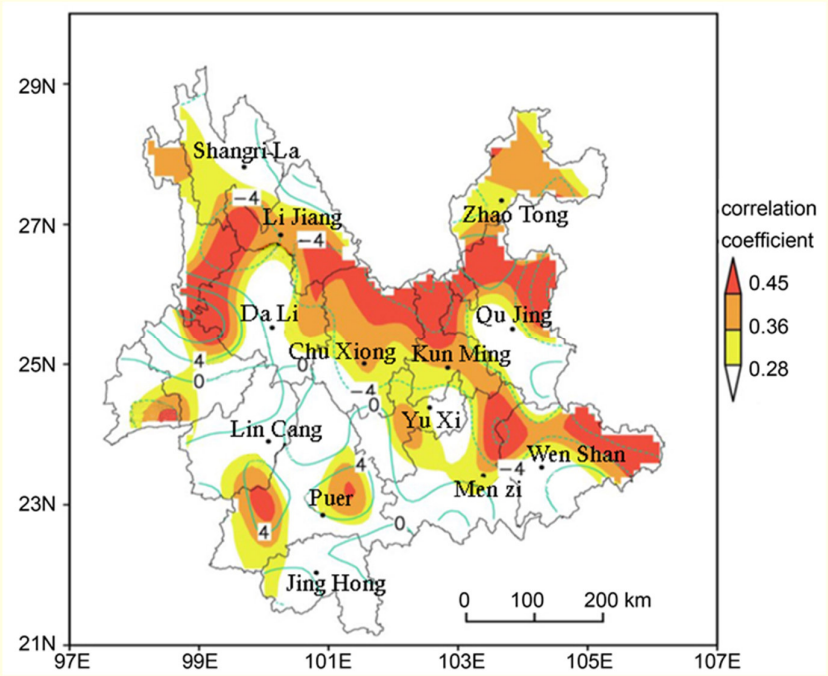


Figure 2. (Select from literature 14). Yunnan change trend of annual sunshine duration distribution and correlation coefficient.

percentage, relative moisture degree index, standard precipitation index, soil relative humidity index, and Palmer drought severity index, as well as the comprehensive meteorological drought index. Huang Zhongyan et al. compared the applicability of meteorological drought index, relative moisture degree index, comprehensive meteorological drought index, precipitation anomaly percentage and standard precipitation index in the agricultural drought monitoring and assessment, thinking that the capacity of meteorological drought index and relative moisture degree index in distinguishing the drought and wetness is superior to the other three indexes. According to the indicative meaning of this index, Ren Juzhang et al. use the relative moisture degree index in 1961-2010 to analyze the space distribution of drought and wetness in the dry/rainy season in Yunnan Region. The drought in Yunnan in the rainy season has the periodical change of 10 - 16 years, 6 - 8 years and 2 - 4 years, and the drought in Yunnan in the dry season mainly has the periodical change of 8 years and 4 - 6 years. Since the start of 21st century, the rainy season in Yunnan gradually becomes dry, and the drought in the dry season slightly increase. This characteristic change mainly results from the non-uniform distribution of precipitation and climate warming in Yunnan since the 1990s, and continuously abnormal drought has happened in Yunnan since 2000 year. The single-station comprehensive drought index is used to assess the drought disaster in Yunnan. The drought in January-March is the severest, and about 2/3 of the land suffers the drought every year; it is followed by November-De- cember, in which about 50% of the land suffers drought, and in first ten days of April - June, 22% of the land suffers drought; in September-October, only 5% of the land suffers drought, and in June-August, less than 1% of the land suffers drought. From analysis on the drought area, it is known that in first ten days of April-June and September-October, drought has the trend of climatic change for development and aggravation.

The change characteristics of multiple drought indexes have indicated that the drought in Yunnan

has the trend of climatic change for development and aggravation, and the drying in Yunnan in the rainy season becomes more obvious. In such climatic context, it is easy to have continuous seasonal drought in Yunnan, just as the continuous drought in the autumn, winter, spring and early summer of 2009-2010, and the relative moisture degree index was obviously smaller in the rainy season of 2009 (or in the later period of the rainy season) (and there was no drought in the rainy season), which is followed by obviously low moisture degree index in the dry season (reflected by typical drought in the winter and spring), and in addition, the rainy season in 2010 started late (reflected by drought in the early summer), resulting in the strongest drought intensity in 2009-2010 since there is the meteorological record and also resulting in the largest disaster and economic loss. After comparing the other three extreme droughts in history (1962/1963, 1968/1969 and 1978/1979), all were continuous seasonal drought, mainly happening in the central and east regions of Yunnan, characterized by long duration and uniform distribution.

4. Causes of Drought in the Low-Latitude Plateau

4.1. Causes of Drought in the Early Summer

May is the transfer period of the dry and wet seasons, and the precipitation amount and the start time of the rainy season are closely related to the agricultural production. Generally speaking, if the rainy season starts earlier with more precipitation, it is more beneficial for the planting of crops sown in the spring, and severe drought in May will influence the output and quality of crops sown in the spring. Therefore, the precipitation in May and the forecast of the start of the rainy season are critical for the meteorological department to provide the decision service for the governments in the levels, and is critical for the short-term climatic forecast in Yunnan.

The rainy season in Yunnan generally happens in the fifth pentad of May. If it is advanced or postponed with two pentads, it is called as the early or late start of the rainy season, and if it is advanced or postponed with three pentads, it is called as quite early start or quite late start. The main causes resulting in early or late start of the rainy season are obvious in the abnormal characteristics of atmospheric circulation in May. In case of the late rainy season, the Eurasian medium-high latitude has two troughs and one ridge in 500 hPa height field in May, and the seasonal northward movement of the westerly is late. The cold air influencing Yunnan is weak, the subtropical anticyclone of West Pacific in the low level is westward, the northward movement of the equatorial westerly is obstructed, resulting in late outbreak and relatively weak intensity of the summer monsoon in the Bay of Bengal and Indochina Peninsula. Yunnan is situated in the sinking branch of Hadley circulation, where the vapor flux is characterized by abnormal divergence, and the water vapor content is smaller than that in the previous years. In case of early start of the rainy season, the circulation characteristics in May are on the contrary.

Such abnormal atmospheric circulation has resulted in continuous little rain and high temperature in May, 2005, forming relatively severe drought. In May, 2005, the whole season transfer is late, the average position of subtropical westerly jet is 6 - 7 dimensions southward by comparison with the same period in history, and the season transfer is obviously postponed, till the South Asia high is stably built on June 5, and the start time of the rainy season is obviously postponed.

The influence of such abnormal circulation is closely related to the abnormal sea temperature of the

Pacific and Indian Ocean in the previous period and in the same period. In the current period, the fall (rise) of the sea temperature in the South Indian Ocean is beneficial (unbeneficial) for the intensification of convection and the formation of the low-pressure system of Bengal region in the early summer, and the low pressure in the Bay of Bengal happens frequently in the early summer, thus the start time of the rainy season in Yunnan is earlier. After the comparison and analysis of the circulation characteristics in May in the drought year and rainy year, it is mainly featured by the westerly vapor transportation in Yunnan in the drought year, which corresponds to the abnormal vapor flux divergence, and the vapor content is less than that in the previous year, and the transfer of the dry and wet seasons is late and is heavily influenced by the inter-annual change of the monsoon intensity in Asia, in which the South Asia high differs obviously and the South Asia high is obviously weak in the drought year. ENSO event on the Pacific Ocean has obvious influence on the start time of the rainy season in Yunnan, and in the EL Nino year, the start time of the rainy season in Yunnan is late, and among 14 EL Nino events, the start time of the rainy season in Yunnan for eight times happened in the sixth pentad of May and later. While in the La Nina year, it corresponds to the early start of the rainy season, and in ten years, there are seven years with normal early start.

4.2. Causes of Drought in the autumn

Autumn is the transitional season from rainy season to dry season in Yunnan, and precipitation is more closely coupled with vapor, and has the distribution characteristics of vector field related to “cyclone-anticyclone” with the whole layer of vapor flux. In the above space of the southwest region, the distribution of the precipitation is differently related to the precipitation in Yunnan in the dry and rainy seasons, and the precipitation in Yunnan in the autumn is in positive correlations with the vapor content in the above space. Therefore, the discussion on the drought in the autumn mostly focuses on the impact of abnormal vapor on the autumn in Yunnan.

With respect to the vapor budget, the precipitation in the autumn in Yunnan is mostly influenced by the vapor inflow in the west and south boundary. In September, the vapor inflow in the west and south boundary in the positive abnormal precipitation years is more than that in the negative abnormal precipitation years, and the outflow in the north boundary is less. In October, the vapor inflow in the positive abnormal precipitation years has the largest difference in the south boundary by comparison with that in the negative abnormal precipitation years. In November, the large difference of vapor flux in the positive and negative abnormal precipitation years happens in the upper layer of the north and east boundary and the whole layer of the west and south boundary. The vapor in the west and south boundary mainly comes from the Indian Ocean and Bay of Bengal, and is transported northward to the southwest region by depending on the monsoon circulation system, thus influencing the precipitation in the autumn in Yunnan, and the formation of drought. If the southwest monsoon and south trough in the autumn are active, the southerly warm and wet air flow influencing Yunnan will become strong and there will be more precipitation in the autumn of Yunnan, otherwise the precipitation will become less, which easily results in drought.

In the autumn of 2009, the height field and circulation between the Bay of Bengal and South China Sea had the asymmetrical change, so that in the space above these two places, the air pressure gradient is abnormally reduced, which has resulted in the abnormal decrease of southwest airflow between the low pressure of the Bay of Bengal and the high pressure of the South China Sea, and

the vapor in the southwest region of China also decreases, and the region between the southwest of China and the Central South Peninsula is under the control of northerly anomaly wind, in the space above the southwest region, there is the abnormal sinking movement, thus the convection movement is inhibited, resulting in the drought in the autumn in southwest China region.

4.3. Causes of Extreme Drought

In recent years, severe drought events happened in Yunnan and its neighboring zones continuously, particularly the drought in the autumn, winter and summer of2009/2010 and 2011/2012 aroused strong repercussion, and many scholars carried out the work of studying the causes of extreme drought. Sun Guowu et al. compared and analyzed the atmospheric low-frequency change characteristics in these two extreme drought years and one non-drought year. Results hold that, there are two flow types for the atmospheric low-frequency change in Yunnan region in the winter and spring: latitude in allow-frequency air flow and longitudinal low-frequency air flow. The former obstructs the north-south exchange of north (south) cold (warm) air flow; the latter ensures that there is no air flow convergence in the single north-south cold and warm air mass. Besides, in the drought year, the low-frequency anticyclone is far more than low-frequency cyclone in southwest region and India-Bay of Bengal region, the northerly air flow in front of the low-frequency anticyclone prevents the northward transportation of the vapor in the Bay of Bengal; in the non-drought year, the low-frequency air flow and the low-frequency system are opposite. Therefore, the change of atmospheric low-frequency air flow and low-frequency system might be one of the reasons resulting in the continuous drought in the winter and spring in Yunnan.

Yunnan is situated in the low-latitude region, and is sensitive in the response to the tropical abnormal circulation. The continuous abnormality of oscillation in the tropical atmospheric season is also one of the reasons for continuous drought in Yunnan. In 2009-2010, one of the main reasons for continuous drought in the autumn, winter and early spring is continuous abnormality in the season in MJO (Madden-Julian Oscillation). In June-October, 2009, the tropical Middle East and Indian Ocean MJO (Madden-Julian Oscillation) index manifests continuous positive abnormality, and correspondingly, atmospheric circulation is characterized by being continuous weak of the convection movement in the Bay of Bengal, and abnormal sinking air flow is triggered in the tropical Indian Ocean region, so that the vertical circulation cell of the Asian monsoon is abnormally weakened in South Asian region, and the vapor transported from the tropical Indian Ocean to Yunnan is abnormally reduced, resulting in continuous decrease of the precipitation in Yunnan from the summer to the autumn in 2009, so drought is formed. In 2009, the winter tropical Middle East and Indian Ocean MJO index maintained positive abnormal status, and the corresponding atmospheric circulation abnormality is maintained, that is, the convection movement in the Bay of Bengal is still weak, the abnormal high pressure ridge appeared from South Asia via Qinghai-Tibet Plateau to the southwest region, Yunnan is situated under the control of vertical sinking air flow of high pressure ridge, which is unbeneficial for the generation of convection movement. Besides, the south trough in the winter has weak intensity, which is unbeneficial for the movement from the Bay of Bengal to Yunnan. So in Yunnan, the precipitation is small in the winter, and drought is intensified, thus forming continuous drought in the autumn, winter, spring and early summer.

After the diagnosis of atmospheric circulation difference in the extreme event years with continuous

seasonal drought, it is found that in the seasonal continuous drought year, the abnormality of the high-latitude Arctic Oscillation (AO) also has influence on the drought in Yunnan. The correlation of AO with the precipitation and temperature in Yunnan in the spring is 0.312 and −0.444 respectively, both passing the 0.05 and 0.01 significance level test. When AO is situated in the negative anomaly status, the middle-latitude air pressure is low, and the air pressure in the polar area is relatively high, the meridional circulation is popular in the middle latitude, cold air is active, but the cold air is easterly and northerly in the southward path, having weak influence on atmospheric temperature in Yunnan. Therefore, when AO is in negative abnormality, the spring in Yunnan is characterized by high temperature and little rain, thus easily resulting drought. Studies have discussed the impact of AO on the continuous seasonal drought in 2009-2010. In the winter of 2009/2010, AO index had the extremely low negative value, reaching the extremely small value since 1951. In such case, the west air flow in the polar vortex and medium and high latitude is weak, the meridional circulation easily appears in the medium and high latitude region, and the cold air movement is frequent. Besides, the subtropical south branch has weak west wind and the south through intensity is reduced, which is unbeneficial for the increase of the precipitation in Yunnan.

Such circulation abnormality happens because tropical West Pacific Ocean and tropical Indian Ocean are situated in the temperature rise period from the autumn and winter of 2009 to the spring of 2010, resulting in the intensification of southwest air flow in the southeast coastal area of China, while the space above South China and Central China regions are under the control of low trough, thus it is controlled by the northwest air flow and sinking air flow behind the trough in the east of the plateau, so that the vapor from the Bay of Bengal is difficult to reach Yunnan-Guizhou Plateau, resulting in the long-term precipitation deficiency in this region. On the other hand, the quasi-stationary planetary wave guide was quite strong in the polar place at the medium and high latitude from the winter of 2009 to the spring of 2010, while low-latitude wave guide was weak, so the latitudinal average westerly was intensified in the medium and high-layer of the convection layer near 35˚N, resulting in very large negative value of AO index, East Asia cold air is weak and has the easterly path, while the cold air movement is weak around the Yunnan-Guizhou Plateau, thus resulting in weak cold air movement in the southwest region of China and long-term precipitation deficiency and severe drought.

In addition to the above circulation abnormality reasons, the development period of El Nino event, attenuation period of La Nina event and relatively high sea temperature of the Indian Ocean are beneficial for the generation and development of drought in Yunnan. Therefore, the extreme drought is related to circulation abnormality, and is also influenced by external signals, such as ENSO.

5. Conclusions and Discussion

1) The climatic change characteristics in Yunnan manifest that the annual average temperature basically has the rise trend, annual precipitation is reduced in the east, northeast, south and west of Yunnan, particularly there is obvious decrease trend of the precipitation in the rainy season. Other factors related to drought, such as sunshine hours influencing the evaporation, have the trend of decrease in the north and increase in the south of Yunnan since 1961, taking Ailao Mountain as the boundary, having the increase trend in the west and south of Ailao Mountain, and decrease trend in the north and east of Ailao Mountain.

2) By using different drought indexes, the drought in Yunnan often happens in the dry season and the extreme drought event often manifests the characteristics of seasonal continuous drought. Since the 1960s, the general trend of drought in the dry season in Yunnan is humidity mitigated and drought intensity increased.
3) The impact factors of drought abnormality in Yunnan are related to the large-scale atmospheric circulation (AO, MJO etc.), abnormal sea temperature of Pacific Ocean and Indian Ocean, vapor transportation path, intensity of equatorial convection and the building of summer monsoon. In the winter and spring, the cold air in the northern hemisphere runs southward in the medium and high latitude and low-latitude warm and wet air is transported northward, which become the main factor of influencing the drought in Yunnan, summarized in Figure A3 of the climatic model.

The direct reason for the drought in a region in a time period is insufficient natural precipitation. Many meteorological scholars have analyzed the causes for drought in Yunnan by starting from the convection factors influencing the precipitation abnormality, holding that the abnormality of low-latitude and medium and high-latitude atmospheric circulation allocation has resulted in the abnormality of time-space distribution for precipitation in Yunnan Region, thus resulting in the happening of the drought events. But Yunnan is situated in low latitude, and is adjacent to Qinghai-Tibet Plateau, there is little study on the impact of the change of large-scale topographic effect of the plateau on the regional drought and on the impact of the sea temperature and circulation in the southern hemisphere, thus further elaborate study is required. In addition to the precipitation factor, the influencing mechanism of other factors influencing drought, such as atmospheric temperature, wind velocity, solar radiation and ground surface situations, isn't so clear.

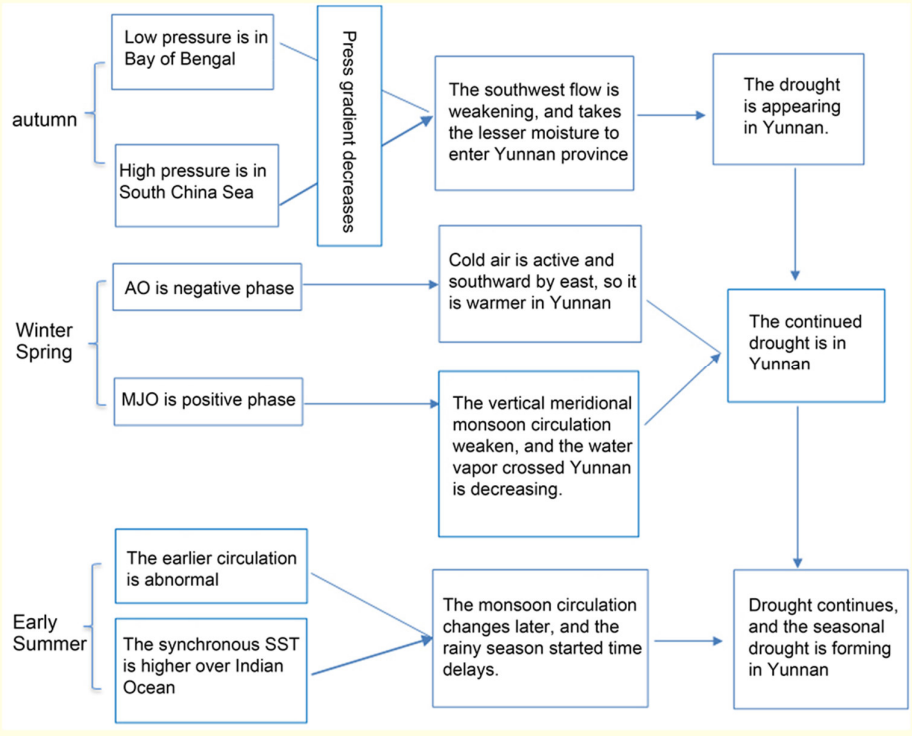


Figure A3. The concept map of Yunnan severe drought causes drought, such as atmospheric temperature, wind velocity, solar radiation and ground surface situations, isn't so clear.

In addition, it is required to deepen the study on the characteristics of continuous drought in Yunnan, that is, the study method for objective identification and analysis of time-space distribution characteristics, duration, happening frequency and intensity change, and the objective assessment method for the drought events in Yunnan.

Annex 4

A Project Climate Risk Assessment and Management Reporting Template

I. Basic Project Information

Project Title: Yunnan Lincang Border Economic Cooperation Zone Development Project
Project Budget: 441.24 Million
Location: Yunnan Province, CHINA
Sector: Urban Development
Theme: Regional Cooperation Initiative
Brief Description: As China's 16th border economic cooperation zone, the Lincang Border Economic Cooperation Zone in southwest Yunnan province was approved in 1992. Since its inception in 2011, the Lincang economic zone has focused on cross-border trade, logistics, finance, tourism, equipment manufacturing and more, facilitating China-Myanmar cooperation. This project is ADB's investment response to the local demand of a piloting modern and environmental friendly border cooperation zone. The project covers three Chinese border cities/towns, namely Qingshuihe, Zhenkang and Cangyuan as shown in Figure 1. 4, along the China-Myanmar border in Lincang prefecture in Yunnan Province in China. The project area is a much less developed area in comparison to other parts of the country in a remote mountainous area. Most of the populations are ethnic minorities consists of Wa, Dai, Yi, Miao, Bai etc. This part of China shares a long inland border with Myanmar without very obvious physical separations, and many local residents from both countries are from the same ethnic groups with similar living styles and habits, and share the similar culture, language, habits and economy. The interactions and exchanges of merchandise as well as border trades have existed throughout the long history of the area. The Asian Development Bank (ADB) and PRC government reached an agreement to use ADB loan of $250 million with a similar amount of counterpart fund from PRC local government for the improvement of regional cooperation and integration facilities and infrastructures to promote the regional cooperation and local economic developmen The project is expected to produce 4 outputs: (i) Cross-border capacity improved; (ii) Integrated urban environmental infrastructures in Qingshuihe border area Improved; (iii) Social infrastructure and service improved; (iv) Institutional capacity of involved agencies Improved.

II. Summary of Climate Risk Screening and Assessment

1: The screening identified **lack of precipitation/drought as a major risk affecting project sitting/design, construction, maintenance and performance**. Drought may cause difficulties in water supply and daily operation of project activities both in domestic and industrial zones. Drought may cause vegetation degradation and biodiversity degradation.

2: The screening identified **extremely intense precipitation and flood as a major risk affecting project design, construction, maintenance and performance.** Especially, extremely intense

precipitation causes considerable damages to construction sites and waste management facilities (both construction phase and operational sites). Extremely intense precipitation and flood can disturb regular operation and maintenance human resource arrangement, in case the project sites have access difficulties.

3: The screening identified **extremely high temperature as a minor risk** affecting project sitting/design, construction, maintenance and performance. High temperature may cause shorter service duration of materials such as landfill liners. High temperature may cause difficulties in operation and maintenance arrangements for project facilities.

4: The screening identified **extreme low temperature as a negligible risk** affecting project sitting/design, construction, maintenance and performance. The lowest temperature recorded by modern methodology in Yunnan Province is – 7.8 Degree Celsius. Low temperature, below – 10 Degree Celsius, may causes damages to buildings during construction phase by low cement solidification. Civil works in winter shall follow the national technical code: JGJ/T 104-2011 Specification of winter construction of building engineering.

A. **Sensitivity of project component(s) to climate/weather conditions and sea level**	
Project component	Sensitivity to climate/weather conditions and sea level
1. Output 1. Cross-border capacity improved. This output is aimed to improve human living quality, efficiency of industrial activities and convenience of cross border transportation in Qingshuihe area. It includes Border Trade Facilities road paving in the border zone. *2.* Integrated urban environmental infrastructures in Qingshuihe border area Improved. This output is aimed to improve the entire performance of the environmental infrastructures in Qingshuihe cross border area. It includes potable water supply system, wastewater treatment facilities, MSW treatment system, River rehabilitation and new energy connecting points. *3.* Social infrastructure and service improved. This output is aimed to increase education and medical capacity of the cross border zone. It includes construction of schools and hospitals. 4. Output 4. Institutional capacity of	1. Intensity and frequency of heavy rainfall events; 2. Extremely low temperature (< - 15 ℃) 3. Drought 4. Flood

involved agencies Improved. This output does not involve any constriction or engineering work.	
B. Climate Risk Screening	
Risk topic	Description of the risk
1. Intensity and frequency of heavy rainfall events and flood	1.1 Project construction sites and operational sites can be affected by floods. 1.2 Extremely intense precipitation causes considerable damages to construction sites, especially road paving workplaces. 1.3 Extremely intense precipitation and flood can damage operational project facilities within the project boundary. 1.4 Extremely intense precipitation and flood can disturb regular operation and maintenance human resource arrangement, in case the project sites have access difficulties. 1.5 Facilities on project sites can be damaged during violent precipitation events and consequential floods. 1.6 Extremely intense precipitation causes considerable damages to waste collection/ wastewater collection sites with flooding and waste/wastewater overflow. 1.7 Extremely intense precipitation and flood can disturb regular operation and maintenance human resource arrangement, in case the project sites have access difficulties.
2. Extremely low temperature	2.1 Extremely low temperature causes considerable damages to buildings during construction phase with structure fractures and low cement solidification. (This risk is eligible) 2.2 Extremely low temperature causes malfunctions of various electronic and mechanical devices associated to the project. (This risk is eligible) 2.3 Extremely low temperature causes water supply paralysis such as water pipeline bursts.
3. Drought	3.1 Drought may cause difficulties in water supply for construction sites resulting project implementation delays. 3.2 Drought may cause difficulties in water supply and daily operation of project activities both in domestic and industrial zones.
4. Extremely high temperature	4.1 Extremely high and extremely low temperature causes ergonomic difficulties for school and hospitals. Young students and patients of hospitals are very vulnerable to extreme temperature. 4.2 High temperature may cause difficulties in operation and maintenance arrangements for landfills and other facilities.

Climate Risk Classification: **Medium**

The overall review for potential climate risk is assessed as medium: The project has high climate risks of violent precipitation, flood and drought. The climate risk of low temperature and high temperature are very small. According to academic studies based on modern observation results, drought intensity and its influence increased in spring, autumn and winter while a slight downward trend exists in summer. Flood intensity and its influence generally showed a downward trend. Flood intensity and its influence in summer exhibited a slight upward trend, while other seasons showed a downward trend. The global gravity of climate risk of Yunnan Lincang Border Economic Cooperation Zone Development Project (The project) is assessed as **medium.**

C. Climate risk assessment

The CRVA mission has reviewed 9 official literatures from World Bank, ADB and other Chinese local reliable research institutions concerning climate risks and climate risk assessment. The climate trends in Yunnan Lincang and harmful climate events to main project components and associated facilities are identified.

The two project phases, both construction and operation works are vulnerable to climate risks.

Extremely low temperature, flood, intensive and violent precipitation events could cause considerable difficulties for construction sites.

During operation phase, roads, general buildings, school and hospitals can be paralyzed or damaged during intensive precipitation and floods.

In the entire design course of this project, anti-flooding measurements must be considered and integrated into detail designs comply with national code and coherent with local anti-flood experiences. Flood is one of the major climate risks for Yunnan Lincang Border Economic Cooperation Zone Development Project.

III. Climate Risk Management Response within the Project

1. Design of building structure, should be to pass a 1-in-100-year flood, plus a standard safety margin, plus a 6% margin for flash flood peaks.

2. Surface water-shedding drainage should be designed for a 1-in-5-year rainfall event.

3. Water pipes and leachate pipes should be resilient against low temperature without frequent severe bursts.

4. Materials and equipment should have enough resilience with margin against 10 days water scouring or soaking.

5. Landscape sites and eventual compensation reforestation shall have emergency irrigation

system to antagonize drought.

6. Project sites shall be equipped with escaping facilities for human evacuation during eventual flooding events.

7. An emergency reaction plan shall be available to evacuate human and equipment during flooding events.

8. Ground surface water-shedding drainage should be designed for a 1-in-5-year rainfall event.

9. Design of facilities and buildings, should be to pass a 1-in-100-year flood, plus a standard safety margin, plus a 6% margin for flash flood peaks.