Climate Risk and Vulnerability Assessment

Project Number: 47152
May 2016

Republic of the Union of Myanmar: Irrigated Agriculture Inclusive Development Project

Asian Development Bank

ABBREVIATIONS

ADB	–	Asian Development Bank
ADRA	–	Adventist Development and Relief Agency
CDZ	–	Central Dry Zone
DAP	–	Department of Agricultural Planning, MOAI
DAR	–	Department of Agricultural Research, MOAI
DOA	–	Department of Agriculture, MOAI
EA	–	Executing Agency
EARF	–	Environmental Assessment and Review Framework
EIA	–	Environmental Impact Assessment
EMP	–	Environmental Management Plan
GOM	–	Government of Myanmar
GRC	–	Grievance Redress Committee
GRM	–	Grievance Redress Mechanism
IEE	–	Initial Environmental Examination
IA	–	Implementing Agency
ID	–	Irrigation Department, MOAI
IAIDP	–	Irrigated Agriculture Inclusive Development Project
IPSA	–	Initial Poverty and Social Analysis
LIFT	–	Livelihoods and Food Security Trust Fund
MOECAF	–	Ministry of Environmental Conservation and Forestry
MOAI	–	Ministry of Agriculture and Irrigation
NECC	–	National Environmental Conservation Coordination Committee
NGO	–	Non-Government Organization
O&M	–	Operation and maintenance
PAM	–	Project Administration Manual
PAP	–	Project affected person
PPMS	–	Project Performance Monitoring System
PPTA	–	Project preparation Technical Assistance
RAP	–	Resettlement Action Plan
REA	–	Rapid Environmental Assessment Checklist
RRP	–	Report and Recommendation to the President (of ADB)
SPS	–	Safeguard Policy Statement 2009 of ADB
WRUD	–	Water Resources Utilization Department
WUA	–	Water User Association
VAO	–	Village Administration Office

WEIGHT AND MEASURES

cm	–	centimeter
cm/sec	–	centimeter per second
dbA	–	decibels
ha	–	hectare
km	–	kilometer
m	–	meter
mm	–	millimeter

NOTE

In this report, “$” refers to US dollars

Contents

I. OVERVIEW

A. Background

1. This Climate Risk and Vulnerability Assessment is prepared and submitted as part of the due diligence under the Project Preparatory Technical Assistance (PPTA) for the Myanmar: Irrigated Agriculture Inclusive Development Project (IAIDP) in the Central Dry Zone (CDZ) of Myanmar. The results will be incorporated in the core subprojects' IEE and the IAIDP Environmental Assessment Review Framework (EARF) for future subprojects.

2. The CDZ is one of the most food insecure, water-stressed, climate sensitive and natural resource poor regions in Myanmar. It has the second highest population density in Myanmar but remains one of the least developed. Access to water is a key determinant of rural poverty, with resources largely dependent on the southwest monsoon. Water shortages caused by pronounced seasonality and very variable annual rainfall patterns, compounded by sandy and fragile soils render rainfed agriculture a high risk endeavor. Under such uncertain climatic conditions, the provision of reliable irrigation is critical for safeguarding crops and sustaining the livelihoods of farmers and farm workers. Many of the irrigation schemes in the CDZ were built many years ago and are in poor condition: they need to be rehabilitated, redesigned and upgraded to meet changing demands and uses.

3. The CDZ is very hot (ranging from 14^{o}C to 42^{o}C), with low rainfall and high evaporation throughout the year. There are pronounced dry seasons and erratic rainfall patterns (both spatially and temporally). Both streamflow and food production are highly susceptible to rainfall variability and it is anticipated that climate change, in conjunction with increased population, will aggravate the imbalance between water demand and supply.

4. The need for irrigation is highlighted by data on monthly rainfall and evaporation as presented in **Table 1** for Pyawbwe/Mandalay (Chaungmagyi) and Myothit/Taungdwingyi (Natmauk). Annual evaporation is approximately twice the annual rainfall; rainfall only exceeds evaporation (and hence meet crop water requirements) in two months – September and October. Irrigation is needed to meet the demands for crop growth in all other months.

Table 1: Monthly Rainfall and Evaporation (mm): Pyawbwe/Mandalay (Chaungmagyi) and Myothit/Taungdwingyi (Natmauk)

Township	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall Pyawbwe	2002-2014	1	0	8	36	126	103	64	98	161	178	43	12	830
Myothit	2005-2014	3	0	1	16	72	147	115	164	165	185	5	9	882
Evaporation Mandalay	2001-2010	102	116	172	199	174	167	172	146	141	132	109	91	1,722
Taungdwingyi	2011-2014	76	103	154	183	185	137	138	161	140	155	73	84	1,587

5. Irrigation provides access to water at times when it is not available from direct rainfall: it is thus in itself an adaptation to an uncertain and unreliable climate, and enables cultivation even in seasons when there is no rainfall. However, the infrastructure to deliver water needs to be resilient against flood and other damage, and it needs to take water from rivers or aquifers which have sufficient supply to meet crop needs. More intense rainfall will increase the risk of flood damage, and changes in rainfall magnitude and timing will influence the water resource. Crop water requirements are influenced by temperature changes, and may be adjusted by choice of crops. Climatic conditions are thus basic design parameters for irrigation systems, and designs must take account of future climate projections – including the greater uncertainty of climate in the future. Systems which were

designed in accordance with an earlier climate may no longer as safe or effective in future, but it should be noted that even if not as good as previously they may still be better than the alternative of rainfed cropping.

6. The Project will finance investments in the irrigation and drainage sector, focusing on surface gravity irrigation systems, to enable crop diversification particularly in the summer season. The Government has identified a list of priority projects, comprising relatively large projects (5,000 to 25,000 acres mostly in two catchments in three districts (Magway, Meiktila and Yamethin). These all need extensive rehabilitation and significant improvements to the arrangements for water management.

7. Table 2 presents a summary of the projects evaluated by the PPTA team. Chaungmagyi in Mandalay and Natmauk in Magway Region were agreed as core subprojects for immediate implementation, with the remainder placed in a potential pipeline for future implementation, to be reviewed under the framework of the IAIDP EARF. Other IEEs and update climate risk assessments may be required in the future.

Table 2: IAIDP Pipeline Projects Evaluated with Core Subprojects

Region / State	System	Storage volume (acre-ft.)	Net command area (acre)	Storage per unit command area (feet)	Average Water Use (acre-ft.)		Cropping Intensity	
					avg	dry yr.	avg	dry yr
Magway	Natmauk	88,400 [(1)]	25,380	3.48	140,255	102,664	119	101
Magway	Sun Chaung	24,576	7,125	3.45	25,212	14,906	130	121
Magway	Saddan	18,000	10,500	1.71	28,956	16,414	115	110
Magway	Yanpe	35,140	10,845	3.24	24,437	1,625	108	103
Magway	Kinpuntaung	10,520	5,190	2.03	13,882	6,651	111	99
Mandalay	Thin Pone	13,059	8,728	1.50			96	79
Mandalay	Meiktila	17,209	26,297	0.65	17,549	10,506	10	7
Mandalay	Chaung Gauk	3,250	6,614	0.49	12,909	8,635	64	51
Mandalay	Chaungmagyi	33,200 [(1)]	7,255	4.58	30,534	21,909	129	97
Mandalay	Thitsone	39,965	12,345	3.24	27,134	13,569	73	30
Sagaing	Kyeepinakk	38,700	5,458	7.09	36,075	22,739	118	64

[(1)] Numbers being refined during feasibility work and may differ slightly in other reports.

B. Project Components

8. The project pipeline and the first two subprojects to be implemented - Chaungmagyi in Mandalay and Natmauk in Magway - are located on **Figure 1**.

9. The project includes two inter-related activities: (i) irrigation development, including both irrigation infrastructure rehabilitation and improvement of management systems and service delivery (Output 1 – Irrigation Development); and (ii) agricultural support for increasing productivity, focusing on value chain development (Output 2 – Agricultural Development). Investments to strengthen agricultural value chains will be made as described in supplementary document 3, since investments in water alone are not sufficient to increase agricultural productivity.

10. These systems provide protective supplementary irrigation for most if not all of the command area in the monsoon season, and full irrigation for a smaller area irrigable in the summer season (typically less than 30%). Irrigation is reported to be inefficient with much water lost through unlined canals and seepage in sandy soils, but the nature of the layouts means that losses at the head are captured and reused further down the system – the nominal efficiency thus increases, but with a time lag so that the start of the season may be

delayed or there may be dry periods during the season as the monsoon rainfall pattern is bimodal.

11. **Table 3** provides a summary of infrastructure improvements proposed for the two core subprojects:

Figure 1:Location of Pipeline and Core Sub-projects

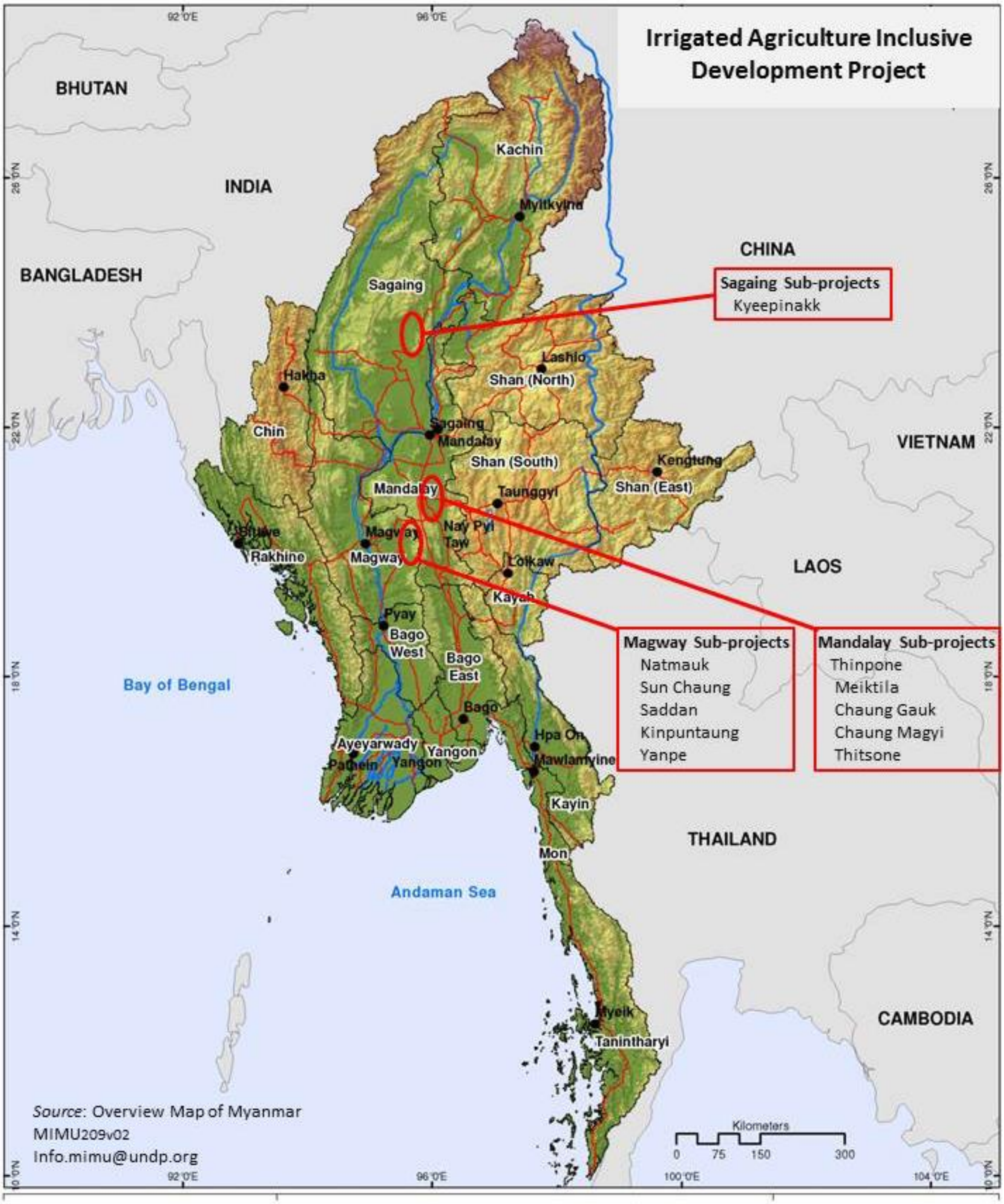


Table 3 Summary of Proposed Infrastructure Rehabilitations at Two Core Subprojects

Type of Interventions	**Unit**	**Number of Interventions (estimated)**	
		Chaung Magyi	Natmauk
Sediment basins at head of main canals	Nr	2	2
Construction of main canal drop structures (ungated)	Nr	20	14
Rehabilitation of main canal drop structures (ungated)	Nr	-	3
Construction of main canal gated cross-regulators	Nr	12	17
Rehabilitation of main canal gated cross-regulators	Nr	-	10
Construction of head regulators	Nr	12	20
Rehabilitation of head regulators	Nr	8	3
Provision of gates to direct outlets (from main canals)	Nr	3	54
Construction of main canal cross-drainage culverts	Nr	-	11
Strengthening of river afflux bunds	Nr	-	5
Removal of sediment from main canals and dispose	100 cft	8,871	48,000
Filling to main canal embankments	100 cft	5,241	23,000
Strengthening and protecting critical reaches of main canal	Km	-	0.25
Lining critical reaches of main canal (erosion and seepage control)	Km	-	4
Construction of bridges over main canal	Nr	7	20
Rehabilitation of bridges over main canal	Nr	10	8
Upgrading main canal inspection roads	Km	19	50
Upgrading dam access road	Km	11	11
Construction of distributary and minor canal drop structures (ungated)	Nr	8	60
Construction of distributary and minor canal gated cross-regulators	Nr	42	140
Rehabilitation of distributary and minor canal gated cross-regulators	Nr	4	-
Provision of gates to watercourse outlets	Nr	75	292
Construction of distributary and minor canal cross-drainage culverts	Nr	-	37
Removal of sediment from distributary and minor canals	100 cft	2,255	20,674
Filling to distributary canals and canal embankments (from borrow)	100 cft	18,435	138,131
Jungle clearance from distributary and minor canals	100 sft	6,448	-
Lining reaches of distributary/minor canals (erosion / seepage control)	km	3	
Flow measurement weirs at head of distributary and minor canals	Nr	15	26
Construction of bridges over distributary and minor canals	Nr	13	73
Rehabilitation of bridges over distributary and minor canals	Nr	4	49
Extension of tertiary watercourses and field ditches	Km	41	288

12. Although there is a common perception that rainfall has declined recently and that the onset of the monsoon has been delayed, this is not supported by the long-term data reviewed in this PPTA or by IWMI’s analysis (2012). Perceptions of change are strongly influenced by recent experience, and the last two years (2014 and 2015) have been very dry, but this is not the same as a climatic trend. Rainfall is highly variable at present and the annual variability in rainfall under present climate is greater than the projections of climate change in the short to medium term.

13. Regional climate modelling reported in the NAPA indicates generally higher temperatures and higher but more intense rainfall in the future although this varies in different parts of Myanmar. Monsoons are likely to become more erratic – shorter monsoons, more intense yet more intermittent rainfall – and thus there will be an increased need for irrigation, whilst at the same time making it more difficult to manage.

14. Irrigation performance is not very good even under present climate, but measures to improve resilience against present climate variability will protect against future climate. However, this variability is expected to increase and thus higher standards of management will be important to reduce the risk of drought or flood damage during the monsoon and to

make better use of scarce water in the dry season.

15. The sub-projects all benefit from water storage facilities which will smooth out the impact of the greater variability in the timing of rainfall. This should make it possible to make better use of any increase in rainfall even if the timing is unsuitable for direct application to crops. The risk of a delayed onset to the monsoon could affect project performance, and improved arrangements for operating reservoirs will be needed.

16. Higher temperatures may affect crop choice and the project design allows for the need to irrigate alternative crops; indeed creating such flexibility is one of the objectives of the rehabilitation.

1. Infrastructure

17. The purpose of the irrigation system is to deliver water throughout the system in agreed and fair manner. Adequately sized canals are required, bounded by continuous embankments with adequate freeboard and stability. Where natural drainage streams cross the canal alignments, infrastructure is required to ensure such drainage flows are taken across the canal safely and to prevent damage to the canal architecture which can compromise the basic conveyance function of the system. The existing infrastructure within the core subprojects (and other potential IAIDP subprojects) does not presently fulfil this requirement, with many low and discontinuous embankments which have been damaged by surface drainage flows.

18. Many main canals do not receive their design discharge at any time, even during the monsoon, and none are operated at full discharge in the summer season. It is only possible to command offtakes in this situation if there are cross regulators to raise the water level at times of low flow. However, many cross regulators are in poor condition or are not operable. Many rely on stoplogs rather than gates. Whilst this is acceptable for small canals, provided stoplogs can be kept available on site, the large canals need gated regulators. Conversely, low level offtakes may take more than their share of water, even when the main canal flow is low. As there are many such offtakes, most of which are un-gated, there is a risk of very inequitable distribution of water – governed more by local topography and outlet configuration than as a result of planned operation. All direct outlets on main and distributary canals should be gated and should enable control of water so that crop water requirements can be delivered.

19. There is usually no constructed drainage system as the undulating topography and natural channels generally provide sufficient drainage, particularly since rice is the dominant crop. Drainage may need to be improved in some areas to enable diversification.

20. Drainage water is often allowed to enter the canals which can surcharge them, causing bank failure and excess sedimentation, and there are significant problems of flood damage to contour canals during the monsoon. High flows from the streams draining the hills to the east and west of the project area are intercepted by the main canals for Natmauk and Yanpe, for example, resulting in the canal banks being severely damaged in several locations. Protection of the main canals is a pre-requisite for any form of irrigation, and will be achieved through provision of adequate cross drainage and improved embankment construction.

21. Detailed designs will take account of best estimates of flood flows, whilst taking account of the risk of increased flood flows under climate change scenarios. Although the increase in risk of flood damage due to climate change is probably small in comparison to the existing risk due to inadequate original design and poor quality construction, both will be

addressed in detailed design. Appropriate return periods and safety factors to allow for climate change will be incorporated in detailed design, and good quality construction will be ensured.

22. Most canals are earthen and unlined, resulting in significant local losses although no data is available either of the magnitude of conveyance losses or of their relative importance as compared to other losses. However, many of these losses are recovered by downstream users within the system, and very little water flows beyond the system boundaries. Although losses may be recovered, better control of water will enable more precise delivery of water to crops and less loss to wasteland and thus will increase the productivity of water. This will require lining in critical locations, but these will be confined to locations where canals are on fill and through sandy soils to ensure value for money. Some lining (brick or concrete) has already been provided in some locations typically close to roads, but decisions on future lining will be based on objective criteria to make best use of scarce water.

23. There is considerable weed growth in some canals as well as sedimentation. Scouring of the bed or slumping of the canal banks are also common problems. Inadequate scour protection downstream of control structures contributes to bank instability as well as undermining structures. All systems need a combination of cleaning, sediment removal, canal re-sectioning and possibly lining.

24. The formal network extends down to minor level; these canals typically command 50 to 500 acres through a number of ungated outlets. Outlet command areas are of the order of 50 acres. Irrigation downstream of the outlet is managed entirely by the farmers through informal cooperation arrangements. There are generally some field channels but the extent and quality of the channels is very variable so much irrigation is field to field. In the case of non-rice crops which cannot be flooded, small temporary channels may be dug along field boundaries to convey water to downstream plots.

25. Roads are generally in poor condition, with even main canal inspection roads often being of low quality. Some tarmac roads cross the sub-project areas, linking townships, but most other roads are earthen and more suited to bullock carts and tractors. Access during the monsoon is thus particularly problematic.

2. Irrigation Management

26. Provision of infrastructure is an essential requirement for improved irrigation, but it is not sufficient on its own: it must be accompanied by improvements to management and associated institutional arrangements. Improved management arrangements will be set up to ensure the sustainability of the infrastructure and the ability to manage it in accordance with agricultural requirements without compromising other water users.

27. A process for strengthening water user participation in system management will be initiated with pilot water user associations set up in three distributary canals in each system. The precise configuration of WUAs will be developed in a participatory manner. Initially these will be informal groups at water course level based around existing *myaunggaungs*. These will be incrementally expanded and formalized through the project.

28. A farmer representative body will gradually be established, with an executive committee charged with undertaking day to day management of the watercourses and participation jointly with the ID on management of distributary canal. The ultimate objective is full management of distributary canals by these new organisations, but it is important not to rush the process and to ensure that they build on existing local institutions. The target during the initial implementation period of the project is WUA management in 15% of the area rehabilitated, to be used as demonstration for gradual extension of improved management

across the entire project area. At least 30% of all farmer committees established will be female, including both female-headed households and female members of male-headed households as representatives.

29. The performance of the ID in managing the main system (including dams) will also be improved, through rationalization of the management committee structure and training of the township and field staff. Improved operational records will be maintained and used for ensuring that actual water distribution is in compliance with the plan. Key indicators will be the numbers of staff trained in asset management and irrigation operation, and the establishment of a comprehensive irrigation asset register and maintenance plan to ensure that infrastructure is kept in good condition.

30. The proposed interventions are focused from Districts down to the level of individual water users. Actions to strengthen management capacity at township levels and amongst water users will additionally reveal reforms needed to the wider institutional and regulatory framework, including for example arrangements for irrigation financing and registration of water user groups. However, the focus of the projects is on developing what exists and building on current capacity rather than to attempt radical innovations from the outset.

31. Coordination between irrigation, agriculture and other technical departments as well as with the local administration is needed to ensure effective and financially sustainable management. Existing agricultural coordination committees and subsidiary committees will be strengthened and made more participatory through a range of activities under the irrigation management component.

32. Activities will be undertaken at several levels to strengthen management of the main system by the ID and other agencies, and to improve communications with users. Thus the component will look at management of all parts of the system and will not only focus on WUAs. Activities will include institutional strengthening and capacity building all with the main organisations:

- Agricultural Coordination Committee (ACC) and Front Line Centre (FLC):
  - improved coordination between DOA, ID, DALMS, water users and others;
  - better crop planning and encouragement of crop diversification to optimize water use.
- Irrigation Department:
  - Systematic asset management to ensure sustainability of infrastructure;
  - Operation planning to meet user requirements within the constraints of water availability, including better management of reservoirs;
  - Monitoring of water distribution and reconciliation with plans;
  - Improved communications with farmers, and coordination with other departments.
- Water users/WUGs:
  - Enhanced role in planning, coordination, conflict resolution and management in tertiary units;
  - Gradual formalization of current arrangements to make more participatory and comprehensive;
  - More systematic involvement in secondary canal operation.

33. The IAIDP concept envisages some crop diversification in both seasons but it is likely that rice will remain the dominant crop. There are alternatives which could give greater returns to water and to labour (which are or will be key limiting resources), but diversification is constrained by multiple factors. The nature and condition of infrastructure and the way it is managed is one factor being addressed through the irrigation component. Other issues (skills, inputs, markets and so) are being tackled through the agricultural component.

34. The project will ensure that the infrastructure can provide the flexibility needed for

mixed cropping and also improve management to reduce the risk that this greater flexibility in operation will result misuse of the system or water theft and conflict. A simple irrigation system gives low outputs but is easy to manage and is relatively resilient in the face of mismanagement. A more flexible, modern system takes more management skill, has the potential to increase productivity (for both individuals and as a whole) but is less robust. The rural economy in the CDZ is likely to change rapidly in the near future and thus the infrastructure and corresponding system of management needs to be adaptable.

3. Chaungmagyi Core Subproject.

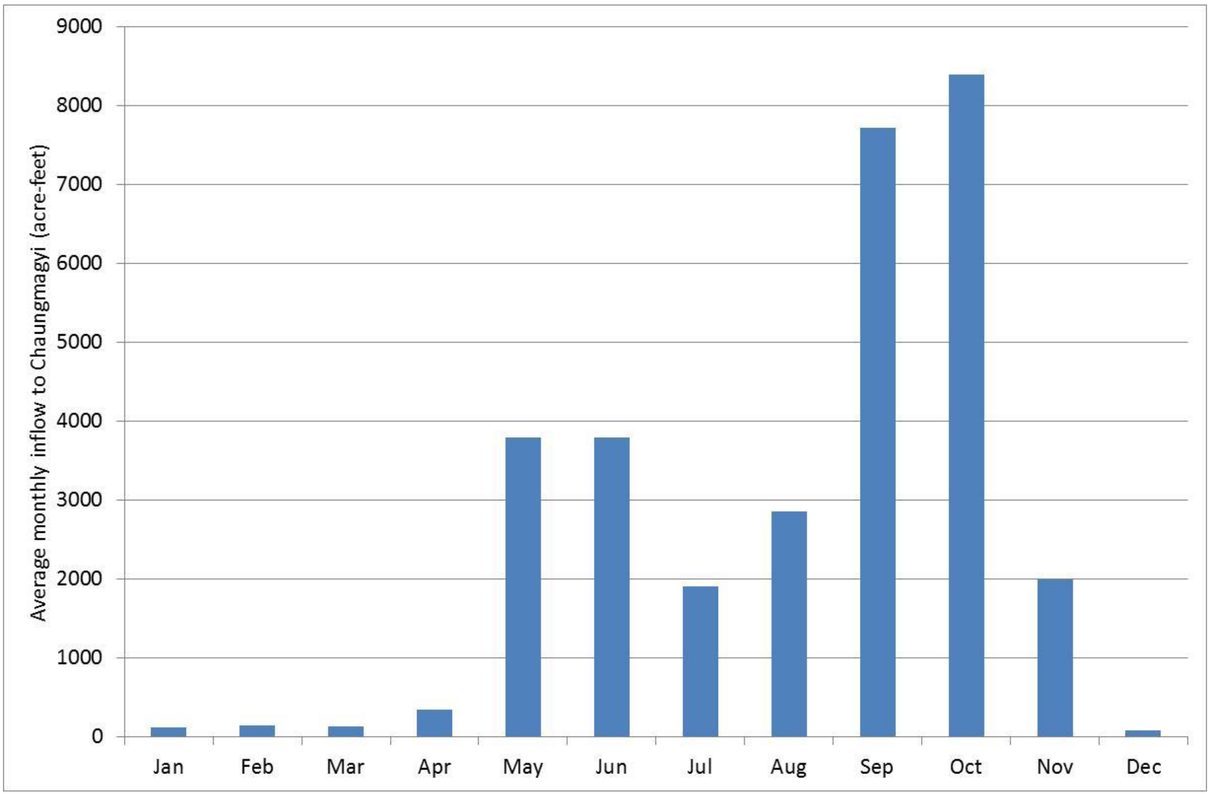
35. **Chaungmagyi** is a small system (about 7,000 acres) completed in 1982 with the potential to increase water utilization significantly if it is rehabilitated, enabling better water control in canal systems, and management of both irrigation systems and the reservoir improved. Increasing productivity will depend as much on agricultural development as the condition and management of the infrastructure. There is a potential saving of water in most years which could be used to increase the summer paddy area (or a proportionately larger increase in alternative summer crops), and efficiency improvements in the monsoon should enable close to 100% paddy in the monsoon.

36. The Chaungmagyi Reservoir on the Chaungmagyi River provides the water for the sub-project area. The average reservoir inflow is about 30,000 acre-feet per year from a catchment area of 93 square miles. The seasonal pattern (see **Figure 2** below) reflects that of the rainfall. The reservoir water is usually fully utilized and there has been spill on only three occasions during the period for which full records are available (2003 to date). The reservoir provides substantial flood protection for areas downstream; many events are fully accommodated in the reservoir while major flood peaks are attenuated. The Chaungmagyi river is one of the headwater streams which drain into the Samon river and ultimately to the Ayeyarwady near Mandalay. There are several diversions and storage reservoirs on the Samon river system which support a large area of irrigation further downstream, so an integrated approach to management considering all users in the (sub-)basin is recommended.

37. The system is in relatively good condition down to distributary canal level although the right canal is heavily silted and few structures provide the degree of water control which is required. The left canal appears to be a scouring channel which will reduce the maintenance requirements at the head but increase the problems at the tail and also undermine structures which generally have inadequate cut-offs. There are some checks with provision for stoplogs and several drop structures all of which are ungated. These provide a limited degree of control but need to be operated with temporary methods such as plastic sheets, sandbags and timbers.

38. The offtakes for distributary canals are fitted with gates and are generally in operable condition. Distributary canals are in much poorer condition, with extensive weed growth and dilapidated structures (often completely bypassed or suffering from severe downstream scour). There are some tertiary canals which are supplied via ungated pipe outlets. There is extensive use of groundwater irrigation for vegetables, notably onions. Some of this land is out of command, but water shortage at critical periods is the main limitation. The groundwater is reportedly slightly saline.

Figure 2:Average Monthly Inflows to Chaungmagyi Reservoir



Data for period 1989-2014

39. The left main canal is 6.93 miles long with nine distributary canals. This is a well-structured system with few direct outlets which should simplify management. The right main canal is slightly smaller and shorter, but similar in layout although it needs more repair work. There are a large number of drops on both main and distributary canals – some are in good condition but others need extensive repairs – for example due to downstream scour or even complete bypassing. These problems cause difficulties in commanding offtakes and hence farmers place informal mud/sandbag checks. There is good road access along the main canals but rarely along distributary canals. Tertiary development is incomplete, being around 20-40%.

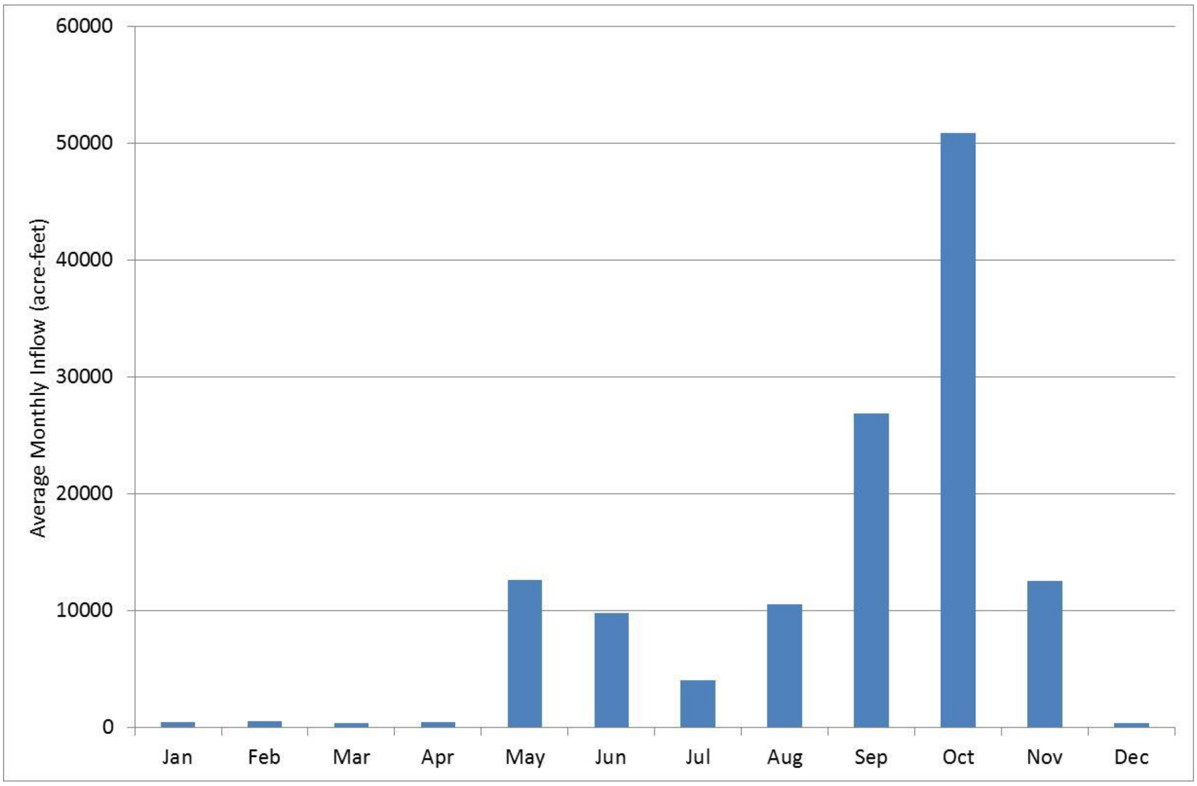
40. Paddy is the dominant crop, but cotton is common particularly in downstream areas where there is a water shortage – despite high theoretical water requirements, very little water is provided for cotton. In addition there are quite extensive areas of vegetables grown in parts of the command area, large from privately managed groundwater. Cropping intensity has dropped in recent years, with significantly lower areas of monsoon paddy and rather more erratic summer irrigation even though total rainfall has not declined significantly. This is believed to be due to the timing of rainfall, and the increasing practice of maximising releases of water in the summer season. The reservoir is thus empty at the start of the monsoon making it difficult to predict the area which can be irrigated and many farmers prefer to grow rainfed chickpeas and other crops rather than wait for release of water for paddy which will be late and uncertain, and has much higher labour requirements. If climate change delays the onset of the monsoon, the need for better reservoir operational planning will become even more important but it will it not reduce the amount of water available for irrigation.

4. Natmauk Core Subproject.

41. Natmauk is a relatively large scheme built in 1995, fed by a dam on the Yin River and supplemented by a major unregulated tributary between the dam and the weir. A feasibility study was undertaken by SMEC (1984). The net command area is around 25,000 acres. There is similar scope for improvement as in the case of Chaungmagyi, and it suffers from many of the same problems.There is severe sedimentation upstream of main canal intakes at weir, largely due to the uncontrolled inflows between dam and weir. This is excavated from time to time but this expensive and only a temporary and partial solution. The canal flows are thus restricted to 100 cusec (about 50% of the design discharge) even in the monsoon. A second major problem is flood damage to the right main canal as there is insufficient cross drainage.

42. The reservoir has an active storage of 86,400 acre-ft plus 12,600 acre-ft dead storage. This is approximately 65% of average annual runoff from its catchment area of 433 square miles but comparable to the one in five year runoff and to the actual annual utilization. In most years (8 out of the last 10) there is sufficient water stored to enable an irrigated summer crop on part of the area. The sub-project area also receives some water from the unregulated catchment between the dam and the main weir; this has a catchment area nearly 30% of that of the reservoir. The average annual reservoir inflow is about 130,000 acre-feet. The seasonal pattern (see **Figure 3** below) reflects that of the rainfall. The reservoir has only filled on two occasions since 2006, but these were major flood events (2010 and 2011) and in each year the amount of water spilled was greater than the average annual inflow. The peak inflow in the 2011 flood has been estimated to be close to 20,000ft^3/s with the peak outflow about half of this. The Yin river drains into the Ayeyarwady river near Magway, but there is no formal abstraction from the river for irrigation downstream of the Natmauk system making an IWRM approach simpler than in the case of the Samon river.

Figure 3:Average Monthly Inflows to Natmauk Reservoir



Data for period 1995-2014

43. There are two large main canals, which are generally in a basic functional condition apart from the flood damage in the head reach of the right main canal. However, there are few cross regulators on the main canals which, combined with low flows, means difficulties in commanding some outlets. The regulators are ungated (although with provision for stoplogs) and some are in poor (inoperable) condition. In some cases (e.g. LMC DY1) a separate low level uncontrolled pipe has been installed to augment the flow into the distributary when the main canal flow is low. The official outlet is just used to irrigate some relatively high land adjacent to the main canal and the unofficial adjacent pipe is used for the bulk of the command. A similar problem arises even with the official outlets.

44. There is said to be a rotation of the right main canal at times of shortage in the monsoon, with the first three DY canals (about 35% area) having water for 3 days and the remaining DY canals (65% of the area) getting water for 4 days (2 days each for DY4/5/6 and 7/8). The tail distributary canals are very long and irrigated large areas with a poor supply – this land is only cultivated in the monsoon, largely from rainfall but supplemented by canal irrigation and drainage reuse. Outlets along the DY canals are nominally the responsibility of the ID although the farmers are actively involved, probably taking a leading role. All outlets are said to be operated simultaneously.

45. The distributary canals are simple earthen channels with few structures. Most outlets are either simple cuts through the bank, or ungated pipes. Operation is thus essentially managed by the farmers, opening outlets to their land and possibly closing upstream outlets. Control is largely achieved by temporary interventions by the farmers, but the larger canals have some formal structures. Some of these are in very poor condition - notably on the long channels at the tail where water supply is erratic and maintenance neglected.

46. Crop data suggests that cropping intensity can reach 130% (almost entirely paddy) in years where rainfall is greater than 25 inches, which has occurred 5 years out of the last ten. Even greater rainfall does not result in a higher cropping intensity as the reservoir spills and water cannot be delivered efficiently to the tail areas. The intensity drops to just 100% if rainfall is less than 20 inches which has occurred twice in the last decade.

47. Table 3 provides an estimate of the anticipated increase in irrigated area, noting that these are not new areas but existing irrigation areas that are not now receiving water:

Table 4 Anticipated Increase in Irrigated Area

Name of System	Irrigated area increase		Overall System area
	Monsoon	Summer	
Chaungmagyi	820	1,294	6,908
Natmauk	1,522	2,474	24,995

II. CLIMATE RISK SCREENING

A. Climatic and Hydrological Trends

48. This section contains summary information on the climate and future projections of climate. More details may be found in the hydrological part of Supplementary Document 2 and the Feasibility Study reports for the two core sub-projects.

49. **Greenhouse Gas Emissions.** Net greenhouse gas emissions from the project will derive from GHGs emitted by agricultural activities – in particular the CH_4, N_2O and CO_2

emissions from rice paddy flooding and cultivation (Galthorne-Hardy, 2013[1]). However, there will not be any significant increase in paddy areas, and agricultural diversification to crops with lower GHG emissions will be promoted. There is a considerable range in GHG emissions depending on cultivation and water management practices and other factors, but using global average figures of about 5 tonnes/ha (WRI[2]), the total emission for the largest sub-project (Natmauk) will be around 60,000 tonnes/annum at present. The change in area will be small and hence change in GHG emissions will be small (of the order of ten percent). Improved management of surface water and control of flooding should reduce emissions, and it may also reduce the requirement for groundwater irrigation and hence pumping. Furthermore, improved quality control of fertilizer should reduce the energy content of active nutrients. In any case, based on the size of the IAIDP subproject areas, the total GHG emissions per sub-project will be well below the threshold of 100,000 tons/annum of the ADB SPS 2009. No detailed assessment was performed and no further monitoring is required.

50. **Climate.** The climate of the CDZ can be divided into two periods—the wet season and the dry season. The wet season coincides with the southwest monsoon and lasts from May to October. The dry season is divided into "winter" (November to February) and "summer" (March to April). Mean annual rainfall in the CDZ is lower than in the rest of the country, ranging from 500 to 1000 mm. The CDZ also typically experiences a brief dry spell during the wet season in June/July. The CDZ is characterized by erratic rainfall. Both streamflow and food production are highly susceptible to rainfall variability. It is anticipated that climate change, in conjunction with increased population, may aggravate the imbalance between water demand and supply. However, currently, there is little understanding of how rainfall is spatially distributed within the CDZ and how rainfall patterns have changed or are changing over time.

51. Rainfall and Evaporation data were presented in **Table 1**. Other key meteorological parameters are presented in **Tables 5 - 7**, for Mandalay (for Chaungmagyi) and Taungdwingyi (for Natmauk).

Table 5 Relative Humidity of Core Subproject Areas (%)

Township	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mandalay	2005-2014	79	66	57	60	70	73	75	79	81	82	79	81	73
Taungdwingyi	2006-2014	59	49	44	46	65	79	81	83	82	81	74	67	67

Table 6 Wind Speed in Core Subproject Areas

Township	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mandalay	2001-2014	0.25	0.53	1.26	1.84	1.70	2.58	2.60	1.66	1.10	0.49	0.26	0.15	1.20

Table 7 Sunshine Hours in Core Subproject Areas

Township	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mandalay	2001-2014	273.7	238.8	252.0	237.5	228.9	200.1	161.3	169.6	166.1	215.7	244.7	251.0	219.9
Taungdwingyi	2011-2014	275.9	254.8	260.4	249	226.3	138.0	158.1	142.6	186.0	223.2	240.0	244.9	220.1

1 http://www.southasia.ox.ac.uk/sites/sias/files/documents/GHG%20emissions%20from%20rice%20-%20%20working%20paper.pdf

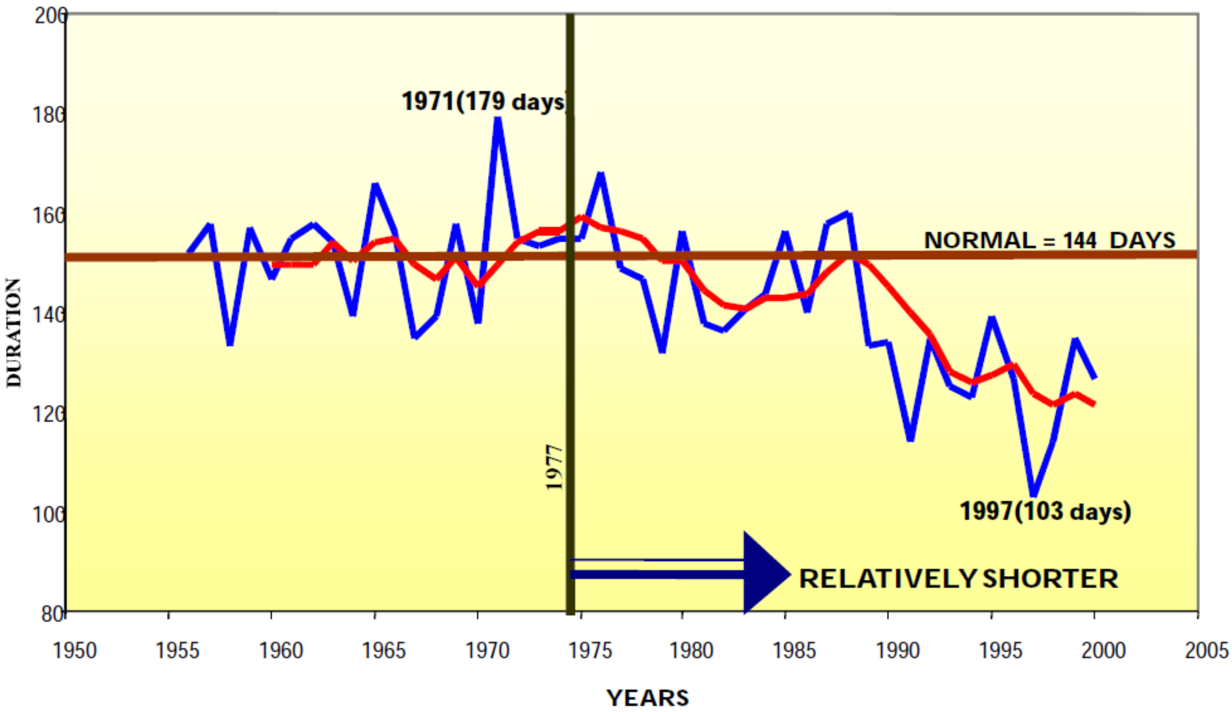
2 http://www.wri.org/sites/default/files/wetting-drying-reducing-greenhouse-gas-emissions-saving-water-rice-production.pdf

52. **Climate variability and projections.** In 2012, Myanmar prepared the "National Adaptation Programme of Action (NAPA)" report giving a country-wide assessment of the risks of climate change and proposed action programs and projects, this included climate change projections, in general terms. These observations were based on PRECIS model outputs, and indicated that there would be:

- a general increase in temperature across the whole country, particularly from December – May with the Central and Northern regions experiencing the greatest increases;
- an increase in clear sky days exacerbating drought periods;
- an increase in rainfall variability during the rainy season including an increase across the whole country from March – November (particularly in Northern Myanmar), and decrease between December and February;
- an increase in the risk of flooding resulting from a late onset and early withdrawal of monsoon events, resulting in a continuation in the trend towards shorter monsoons as indicated in **Figure 4** (from the NAPA) given below;
- an increase in the occurrence and intensity of extreme weather events, including cyclones/strong winds, flood/storm surge, intense rains, extreme high temperatures and drought.

53. It should be noted that this is based on a single model output, but other models suggest also an increase in variability although there is little consensus on the magnitude or even direction of changes

Figure 4: Duration of the Monsoon

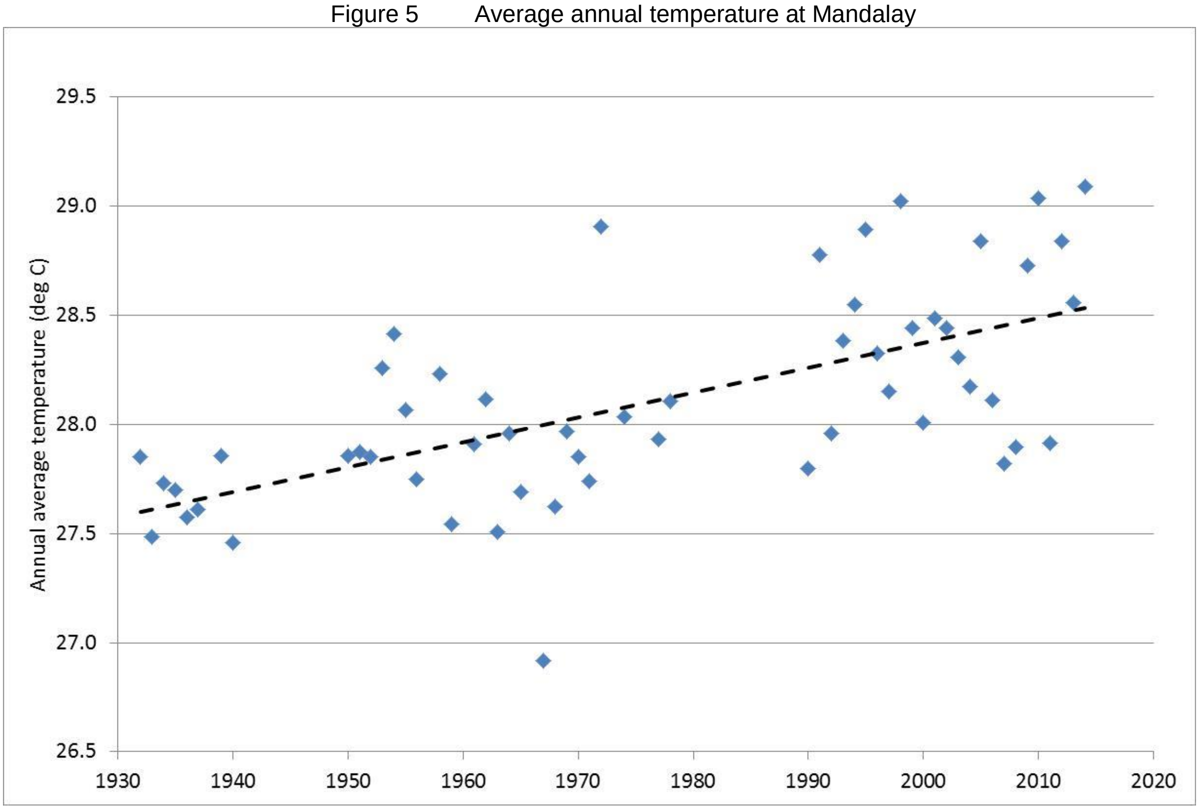


54. The NAPA noted that over the last six decades (1951 to 2007), the temperature in Myanmar has increased on average by ~0.08°C per decade. This has been reflected by fewer cold days and more frequent hot days. Despite overall trends of increasing temperatures, five regions have experienced decreases. Appreciable decreases include Magway (-0.23°C per decade) and Bago (-0.16°C per decade). The highest warming (~0.32°C per decade) has been experienced in the Kayin State. From 1951 to 2000, ~15 heat waves occurred per year. The most extensive heat wave (covering up to 60% of the

country) occurred in 1998 during an El Niño Southern Oscillation (ENSO) year.

55. Although the data reported by NAPA for Magway and Mandalay reported a slight decrease in temperature, this was not evident from a review of available meteorological data for the subproject areas – this is probably because of the quality and location of temperature measurements in the sub-project areas, which are not at formal meteorological stations. **Figure 5** shows the long-term temperature trends for Mandalay. Temperature data for Mandalay (1932-2014, though with some gaps) shows a rising trend, averaging more than 0.1°C per decade, which is consistent with the data reported in the NAPA.

Figure 5 Average annual temperature at Mandalay



56. **Increase in extreme high temperatures.** There has been a general increase in temperatures across Myanmar over the last six decades. This has resulted in an increase in extreme high temperature days and thus the prevalence of heat-related disorders. During summer 2010, 1,482 heat-related disorders were reported and 260 heat-related deaths occurred across Myanmar. These increases are projected to increase in all months, and there is much greater consensus between models on the magnitude of temperature changes for given scenarios.

B. Floods and Extreme Rainfall Events

57. Flooding is a common phenomenon in Myanmar, although this is mainly a concern in the delta and other coastal regions, with 12 major floods in the 20th century. Hydro-meteorological hazards have impacted food security of many provinces in Myanmar in the past, and are probably the main triggers. Table 9 below shows that these are main factors that could affect both agricultural production and livelihoods of communities. However, most of the food insecure zones have rated drought as the major agricultural production problem in the Dry Zone assessment carried out by WFP (2011).

Table 8 Major climate-related disasters in Myanmar (**1928 to 2011)**

Disaster	Date	No. Total Affected
Storm	2-May-2008	2,420,000
Flood	15-Jul-1974	1,400,000
Storm	23-Oct-1965	500,000
Flood	13-Jul-1991	359,976
Storm	22-Oct-2010	260,049
Flood	Jun-1976	200,000
Storm	21-Apr-1936	150,000
Mass Movement Wet	17-Jun-2010	145,000
Flood	21-Aug-1997	137,418
Storm	17-May-1978	132,000

Source: *EM-DAT: The OFDA/CRED International Disaster Database (www.em-dat.net - Université Catholique de Louvain, Brussels, Belgium)*

58. There is no significant historical record of flooding in the CDZ. One of the largest floods was in 2002 which caused serious damage to lives and farms in Meiktila and the neighboring Wundwin Township. About five people from Meiktila and about nine people from Wundwin were killed by this flood and a small area of farmland was damaged. Families of Thetaw village under the Mongtaing Dam in Meiktila Township were later relocated to the new area due to this flood. Flooding was also a problem during 2015 in parts of Myanmar including parts of the CDZ and causing slight damage to the Natmauk system (although the damage was quickly repaired without disruption to irrigation). There is however no dedicated database or information to archive the impacts of these extreme events at provincial and village levels. The global databases such as the CRED EM-DAT are designed to catch only the major events that are significant at global or national scales. From the perspective of food security decisions are significant at different levels.

59. Flooding in the core subproject areas is largely mitigated by the upstream dams which give some protection to downstream irrigation infrastructure. Most of the damage from flooding in these areas has been caused by inadequate cross drainage from tributary rivers which are not regulated by reservoirs. This situation will be mitigated by the improved infrastructure.

60. Myanmar is exposed to the threats of cyclones and associated surge in the sea-water which cause damage to the coastal areas. The damages were particularly severe in case of Cyclone Nargis. Based on historical records, only about 6.4% (ADPC, 2009) of the cyclones that form in the Bay of Bengal reach or cross the Myanmar coast. Evidences of changes in the long-term cyclone frequencies are unclear at present, but any increase in frequency can also impact the CDZ. Severe damages were experienced in Myanmar during 2015, when flooding occurred mainly in Chin State but also in the western part of the CDZ.

61. **Droughts.** NAPA indicates that drought years with moderate intensity were frequent in the 1980s and the 1990s. Extended dry seasons and increased temperatures have however caused an increase in the prevalence of drought. Severe droughts have increased in frequency from 1990 to 2002. In 2010, severe drought diminished village water sources across the country and destroyed agricultural yields of peas, sugar cane, tomato, and rice.

C. Climate Model Studies

62. The predictions of NAPA, presented below, were compared to those of FAO in 2011. [“Managing Climate Change Risks for Food Security in Myanmar, 2011” by FAO] Synthesis of the climate scenario projections for the end of the 21st century reported for the region indicated that rising temperatures would be accompanied by increased rainfall and runoff during the summer monsoon season. The extremes between wet and dry season rainfall

would increase with some areas experiencing more extended dry periods. A full range of predictions from CMIP5 can be obtained from the World Bank climate portal, and these highlight the increase in uncertainty in the magnitude and timing of rainfall (http://sdwebx.worldbank.org/climateportal/index.cfm).

Figure 6 Projected Change in Temperatures

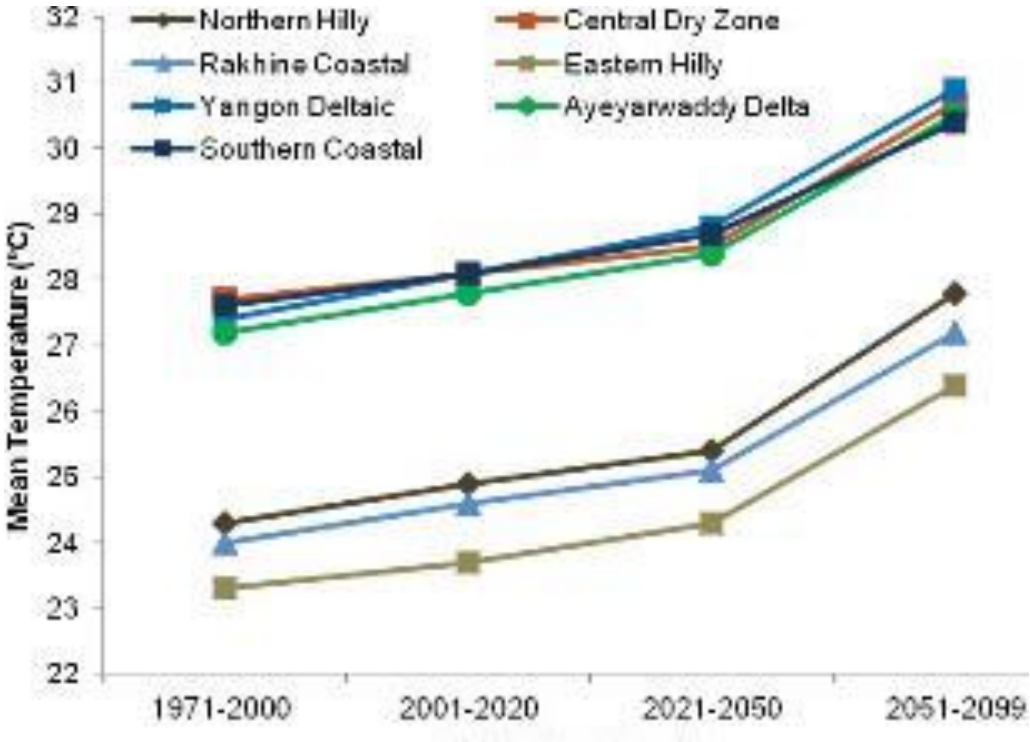
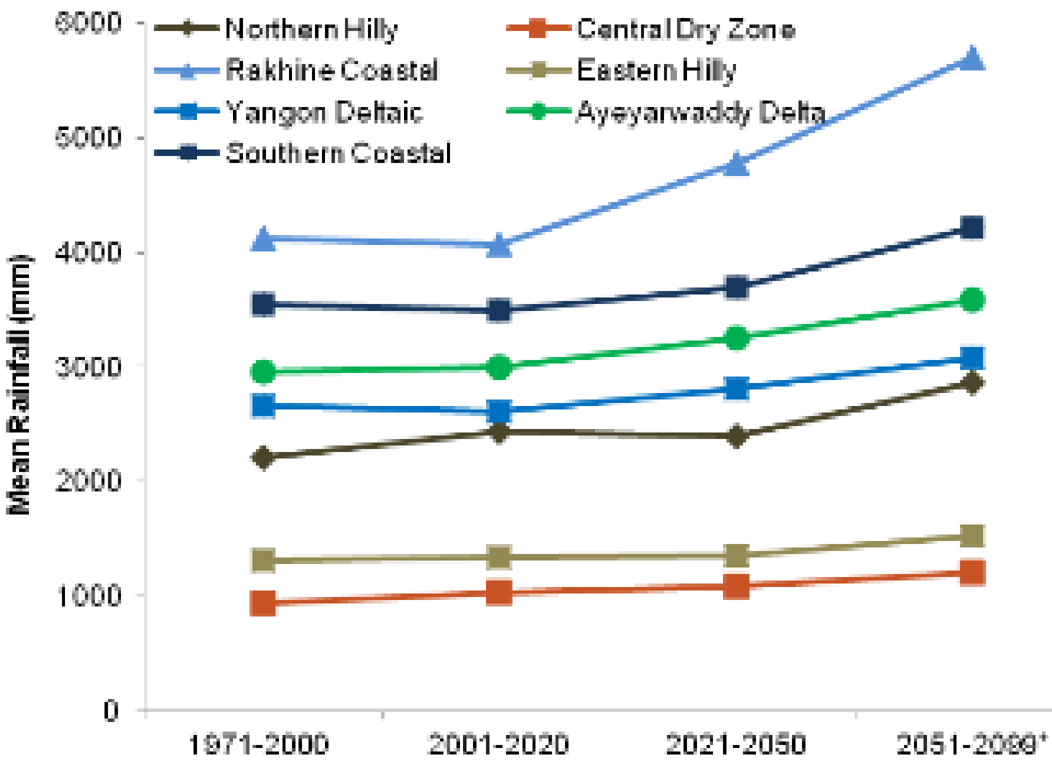


Figure 7 Projected Change in Precipitation



63. The projected scenarios for mean temperatures over Southeast Asia IPCC (2007) indicate increases of between 0.75–0.87°C by 2039, 1.32–2.01°C by 2069, and 1.96–3.77°C by 2100. The specific values for locations within this range of temperature increase would depend on assumption of global emissions, choice of climate models and location. The increase is also expected to be more or less similar across all the seasons. By 2050, Southeast Asia's precipitation will increase 1% under A1FI and 2.25% under B1, with the strongest rise starting in December and ending in May.

64. The fifth assessment report of the IPCC highlights changes in extremes as well as trends in averages. However, although the frequency of heavy precipitation events is increasing generally in South and Southeast Asia, decreasing trends in such events are reported in Myanmar (IPCC, 2013).

65. The AR4 assessed that warming is very likely in the 21st century and that assessment still holds, according to results of the Coupled Model Inter-comparison Project Phase 5 (CMIP5) simulations under all four Representative Concentration Pathway (RCP) scenarios. Projections of future annual precipitation change are also qualitatively similar to those assessed in the AR4.

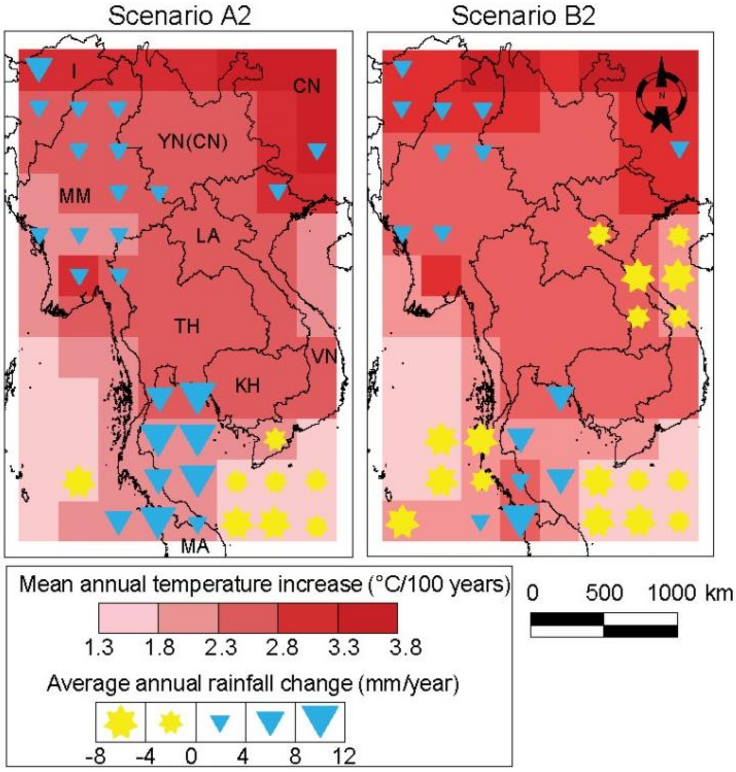
66. CMIP5 models, reported in AR5, project an increase in mean precipitation in the monsoon as well as in inter-annual variability and extremes. All models project an increase in heavy precipitation events and there is general agreement on an earlier onset and later retreat, and hence longer duration with an increase in total precipitation

67. AR5 does not report on the impact on water resources in Myanmar, although the almost adjacent Chao Phraya River basin in Thailand is projected to have a reducing dry season discharge and this is matched by projections for India. A reduction in dry season discharge would be a prudent assumption, based on the historically unreliable and unpredictable dry season rainfall patterns. However the existence of reservoirs with capacity for storage of the annual runoff means that these schemes are able to cope with seasonal variations in rainfall and hence runoff.

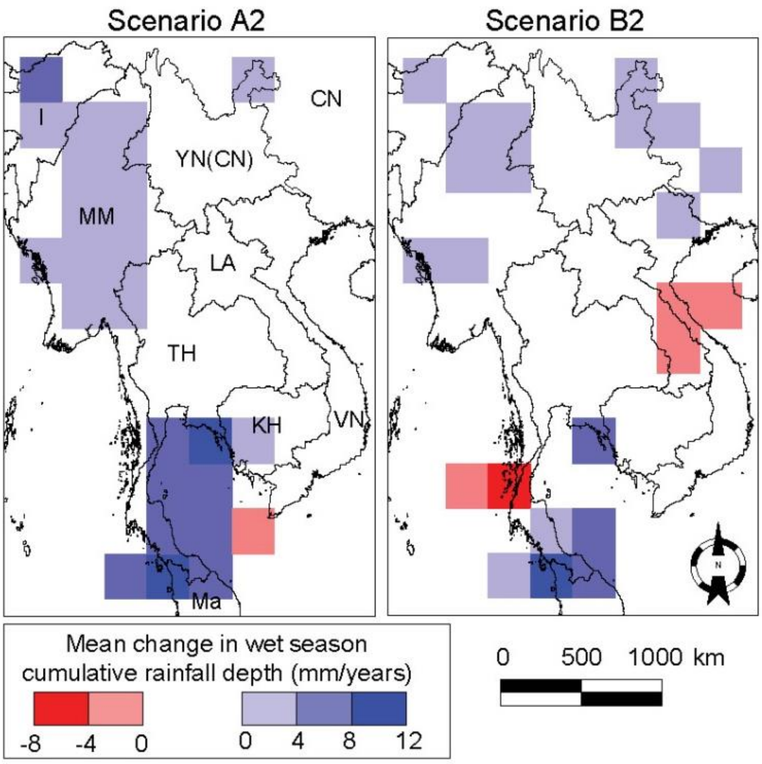
68. In terms of options for adaptation to a future climate, AR5 notes the limited scope for water resource adaptation; options include developing water saving technology, changing drought-resilient crops, and building more water reservoirs. Making better use of limited water resources (through better control of water, more precise delivery to crops and reducing non-evaporation) is a major objective of the IAIDP and existing reservoirs have sufficient capacity to make better use of available storage through improved management.

69. IWMI (2010) report projections of annual rainfall and average temperature across the region although they note that there is considerable variation between different models and that specific outputs from the projections should not be used for adaptation planning: they observe that "*it is more useful to characterize likely change as an increase in the variability and uncertainty of water availability"*. They also state that the incremental changes are small in comparison to annual variability and in relation to social, demographic and economic drivers of change. Thus they recommend a 'no regrets' approach with actions to promote water use productivity and use of storage.

70. IWMI also note that global projections indicate that the incidence of extreme climate events is likely to increase, and that "*changes in the patterns of storm activity could impact on rainfall and runoff distribution…. damage due to flooding was more serious than actual storm damage*"



a) Annual temperature and rainfall change over the period 1960-2049.



b) Changes in wet-season cumulative rainfall depths over the period 1960-2049.

D. Climate Screening and Adaptation

71. **Climate variability and change adaptation measures.** The potential for the IAIDP to be affected by future climate change was considered during the IAIDP PPTA IEE preparation through the use of the ADB-approved AWARE screening tool. This screening assigned the project a "medium" climate change risk category and identified the risk of flooding as the most severe potential concern. Other risks of lower concern identified were reduced precipitation (lower dry season rainfall of particular concern as well as delays in onset of monsoon), offshore storms and changes is available solar radiation. Increased rainfall could require a change in cropping while reduced or more erratic rainfall can make crops more vulnerable and less productive.

72. Considering the potential impacts to IAIDP infrastructure, this screening identifies **drought, increased temperature** and **floods** as the key risk areas influencing design, maintenance and performance. Droughts were identified as affecting water availability and demands, requiring crop and irrigation planning and careful calculation of crop water needs as a response. Floods were identified as dangers to canals and structures, which need to be designed accordingly. It is noted that irrigation infrastructure by its nature provides some adaptation to climatic variations and are designed to buffer soil moisture deficits and remove the agricultural production risk both in farming systems.

73. **Adaptation.** The Project will continue to use all available water, except during floods. The availability of water is already much less than the demand, but it is still beneficial to use this limited water supply for irrigation as it increases agricultural productivity over the command area. Although some models predict increases in total rainfall, the actual availability may still decline slightly in future at certain times (particularly through a delayed start to the monsoon) and might mean a lower irrigated area in some years than would have been the case if there had not been climate change. A greater proportion of rainfall may occur in major floods which may then occasionally exceed the storage capacity. However, project activities will enable better use of the reduced amount of water, through better operation of reservoir and control of water in the irrigation system, and will still be able to increase the crop areas and yields in comparison to the without project situation.

74. The IAIDP project area suffers from damage due to inadequate cross drainage and poor embankment construction. These will be addressed in rehabilitation, for which the detailed designs will take account of best estimates of flood flows. These may be slightly greater than flow estimates for the 'without climate change' situation, and culverts will be sized accordingly.

75. The increase in risk of flood damage due to climate change is, however, small in comparison to the existing risk due to inadequate original design and poor quality construction, which has already led to considerable flood damage. Both of these problems will be addressed in detailed design and construction, with future design parameters taking account of climate change. The redesign and refurbishment of the schemes offers many opportunities to rectify past defects, and to provide robust structures for future flooding. Appropriate return periods and safety factors to allow for climate change will be incorporated in detailed design, and good quality construction will be ensured. Normal good engineering practice will lead to a considerable increase in flood resilience, even allowing for climate change.

76. Sedimentation may also increase as a result of more intense rainfall, particularly in those sub-projects where there is inflow between the dam and the irrigation system. This is already a problem as there are no sediment exclusion structures. However, sediment settling basins will be provided as they are needed even under the present climate scenario but they will be sized to take account of future anticipated sediment loads. Sedimentation within

reservoirs is another area of concern which may increase in future as a result of more intense rainfall, although it should be noted that reservoirs rarely spill at present and thus there is generally adequate storage available.

77. Climate change can be expected to exacerbate the existing risks (low flows, flood flows, sediment), but measures which are needed for normal good engineering practice to address these existing risks will be effective against future risks. Design parameters will take account of future climate, and the additional cost for the slight increase in the size in drainage culverts will be very small in comparison with cost of basic provision of culverts which will be needed in any climate scenario.

78. As part of normal good practice for addressing existing problems, the IAIDP will thus mitigate additional climate risks; the project will performs on its own merits as an adaptation measure. For the most part irrigation is an adaptation to a very variable climate and thus needs to be flexible to cope with uncertainty. The projected future changes in climate are small compared to existing annual variability in key parameters over the lifetime of the project. Climate variability may increase, but the greater flexibility built into the system through modernization of infrastructure and better management will address this variability.

79. If there is a delay in the onset in monsoon (which appears likely) then reservoir operations might need to be adjusted to ensure storage at the end of the dry season. This is an operational decision and will depend on having the political will not to irrigate too large an area in the summer. Improved operational rules will be developed to provide a scientific basis to support seasonal decisions on crop areas. Operational plans and operating practices for water allocation will be prepared by the PMU during implementation, and will be adopted by ID before completion of works on main canals.

80. The impact of watershed management on water availability, and potential reduction of sedimentation will be investigated by the connected GEF pilot program and results incorporated into the detailed design of core subprojects and subsequent subprojects.

81. There is insufficient information currently to determine if cropping may need to be modified in the CDZ based on projected increased temperatures or rainfall. There is no indication that crop patterns will need to change for climatic reason, but the project is designed to cope with diversified cropping. Paddy is, however, the most resilient crop for anticipated rainfall and temperature patterns.

82. The incremental cost to the IAIDP project costs due to climate change adaptation and mitigation are minimal since they are embedded in good design engineering. They are likely less than 1% of capital costs.

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