# Climate change and groundwater resources in Myanmar

Than Zaw[1*], Maung Maung Than[2]

[1]Groundwater Division, Head Office, Irrigation and Water Utilization Management Department, Ministry of Agriculture, Livestock and Irrigation, Myanmar.
[2]Bago Regional Office, Irrigation and Water Utilization Management Department, Ministry of Agriculture, Livestock and Irrigation, Myanmar.

**Abstract: Myanmar is located in Southeast Asia within the Mekong River Basin. The estimated annual surface and groundwater potentials are 1 081 km$^3$ and 494 km$^3$, respectively. Based on geological conditions, 11 different types of aquifers have been classified in Myanmar. The recent alluvial formation, Irrawaddy formation, Upper Pegu Group and Plateau limestone formation are the major water-bearing geologic formations of the country. In Myanmar, 89% of the groundwater is used for agriculture, approximately 8% is used for domestic consumption, and 3% is used for industrial purposes. Climate change projections for Myanmar from 2001 to 2100 predict general increases in temperature, clear-sky days, rainfall variability and flooding risks and a greater occurrence and intensity of extreme weather events across the country. Additional technology and investments are required to achieve groundwater resource security in response to climate changes. In addition, methods of ensuring the sustainability of groundwater resources must be implemented via collaborations with other countries and international sources.**

**Keywords: Mekong River Basin; Myanmar; Groundwater resource; Aquifer; Climate change; Sustainability**

## 1 Introduction

### 1.1 Land area and boundary

Myanmar is geographically located in Southeast Asia between 9° 32' and 28° 31' north latitude and 92° 10' and 101° 10' east longitude, and it has a total land area of 676 557 km$^2$. Myanmar borders China to the north, Thailand and Lao PDR to the east, India and Bangladesh to the west and Thailand to the south. The country is characterized by mountain ranges in the north, east and west and a long coastal strip in the south and west. The location map of Myanmar is shown in Fig. 1.

### 1.2 Population

The population of Myanmar in 2014 was estimated at 51.486 million, and the rural population accounts for approximately 70% of the total population. According to the 2014 census, the population growth rate was approximately 0.89% and the average population density of the country was 76 persons/km$^2$.

### 1.3 Climate and rainfall

Myanmar has three distinct seasons. The cold season starts from November and extends to the end of January; the dry season starts from February and extends to April, and then the wet season begins. Myanmar receives most of its annual rainfall from the southwest monsoon starting in mid-May and extending to October. Approximately 90% of the annual rainfall in Myanmar occurs during the monsoon season. The rainfall intensity, pattern, and rainy duration show strong variation depending on the location and elevation of the region. The annual rainfall is approximately 2 030 mm to 3 050 mm in the deltaic area, 2 030 mm to 3 810 mm in the north, 1 500 to 2 000 mm in the eastern hilly region, 5 080 mm in the coastal regions of Rakhine and Taninthayi and only 760 mm

*Corresponding author. E-mail: tzaw.wrud@gmail.com

in the central dry zone. Water loss by evaporation is high in general and ranges from 1 500 to 2 000 mm/yr. Because of the climatic variations, water resource scarcity during the dry season becomes a main issue in many parts of the country. The annual rainfall isohyets map is shown in Fig. 2.


**Fig. 1** Location map of Myanmar

## 2 Status of groundwater resources in Myanmar

Myanmar is a water resource abundant country that could be classified as presenting low water stress. There are four major river systems in Myanmar as follows: The Ayeyarwaddy, the Thanlwin, the Chindwin and the Sittoung. These river systems have provided the country with abundant surface water resources. Because of favorable climatic conditions and physiographic features, there are eight river basins that cover approximately 90% of the country's territory. The total surface and groundwater potentials of Myanmar are approximately 1 081 $km^3$/yr and 495 $km^3$/yr, respectively. The details are mentioned in Table 1.

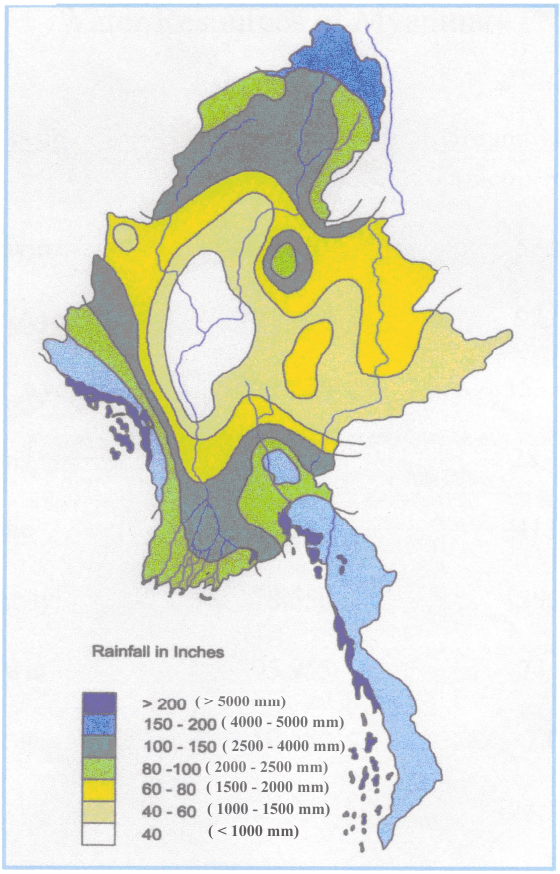


**Fig. 2** Annual rainfall map of union of Myanmar

**Table 1** Myanmar's annual average water resources potential by river basin

| Region/river basin | Surface water ($km^3$/yr) | Groundwater ($km^3$/yr) |
|---|---|---|
| Region 1. Chindwin | 141.293 | 57.578 |
| Region 2. Upper Ayeyawady | 227.920 | 92.599 |
| Region 3. Lower Ayeyawady | 85.80 | 153.249 |
| Region 4. Sittoung | 81.148 | 28.402 |
| Region 5. Rakhine | 139.245 | 41.774 |
| Region 6. Tanintharyi | 130.927 | 39.278 |
| Region 7. Thanlwin | 257.918 | 74.779 |
| Region 8. Mekong | 17.634 | 7.054 |
| Total | 1081.88 | 494.71 |

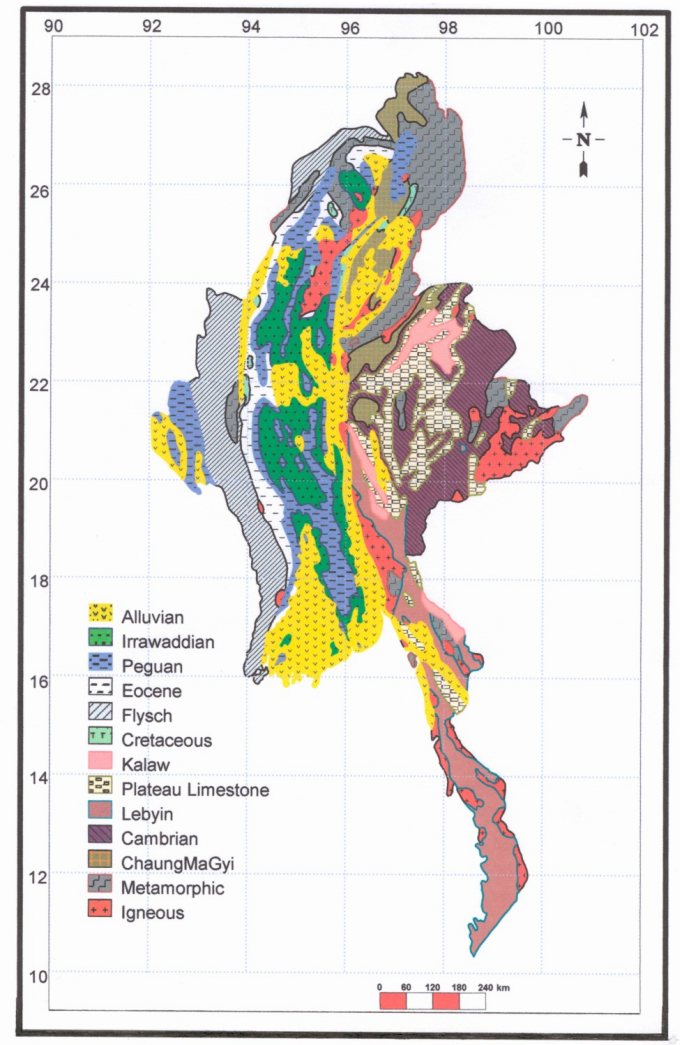


**Fig. 3** Aquifers in Myanmar

Based on stratigraphy, there are eleven different types of aquifers in Myanmar (Fig. 3, Table 2). Depending on their lithology and depositional environment, groundwater from those aquifers varies in quality and quantity. Of these, groundwater from alluvial and Irrawaddian aquifers is estimated to be potable for both irrigation and domestic uses. Groundwater extracted from the Peguan, Eocene and Plateau limestone aquifers are used for the domestic water supply in water scarce areas, although these aquifers are not suitable for drinking purposes.

## 3 Climate change in Myanmar

The climate change projections for Myanmar from 2001 to 2100 are as follows (NAPA, 2012):

-General increase in temperature across the whole country, particularly from December-May with the Central and Northern regions experiencing the greatest increases;

-Increase in clear sky days exacerbating drought periods;

-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;

-Increase in the risk of flooding resulting from a late onset and early withdrawal of monsoon events;

-Increase in the occurrence and intensity of extreme weather events, including cyclones/ strong winds, flood/storm surge, intense rains, extreme high temperatures and drought.

Projected changes in temperature and annual rainfall in each physiographical zone in Myanmar (Fig. 4) are presented in Fig. 5 and 6, respectively. Details of the projected climate changed trends across Myanmar are shown in Table 3.

**Table 2** Description of aquifers in Myanmar

| Sr.No | Name of Aquifer | Major rock units | Area of occurrences | Remarks |
|---|---|---|---|---|
| 1 | Chaungmagyi Aquifer | Low grade metamorphic rocks | Eastern Highland | To be studied in detail |
| 2 | Cambrian-Silurian Aquifer | Molohein Group<br>Pindaya Group<br>Mibayataung Group | Eastern Highland | To be studied in detail |
| 3 | Lebyin-Mergui Aquifer | Graywecke , quartzite, argillite, slate,mudstone, gravel *etc.* | Western boundary of Eastern Highland and Taninthari ranges | To be studies in detail |
| 4 | Plateau Limestone Aquifer | Limestone & dolomite | Western boundary of Eastern Highland and Taninthari ranges | To be studied in detail |
| 5 | Kalaw-Pinlaung-Lashio Aquifer | Loi-an Group &<br>Kalaw Red Bed | Eastern highland | To be studied in detail |
| 6 | Cretaceous Aquifer | Flysch unit and limestone units | Northern Kachin and Western Ranges | To be studied in detail |
| 7 | Flysch Aquifer | Interbedded units of sand, siltstones, shale and mudstone | Western Ranges | To be studied in detail |
| 8 | Eocene Aquifer | Sandstones, siltstones and shales | Central lowland and Rakhine Coastal Plain | Thick aquifer fresh GW with high iron content |
| 9 | Pegu Group Aquifer | Sandstone, siltstones and shales | Central lowland and Rakhine Coastal Plain | Mostly water, some fresh water in recharged areas |
| 10 | Irrawaddian Aquifer | Mainly sands, sandstones with gravels, grits, siltstones and mudstones | Major river basins and its tributaries, base of mountain ranges | Thick aquifer fresh GW with high iron content |
| 11 | Alluvial Aquifer | Sands, gravels and muds | Lowland areas | Fresh GW, seasonal water table changes |

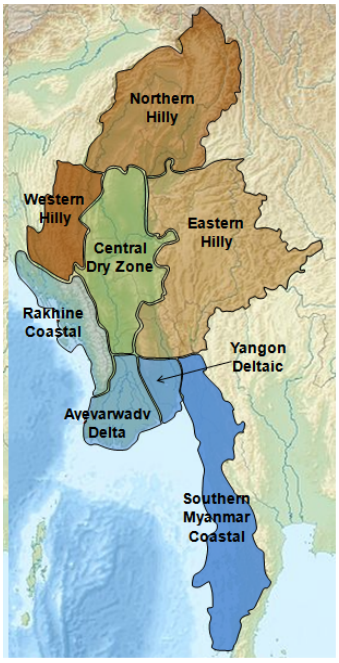


**Fig. 4** Seven physiographic regions in Myanmar

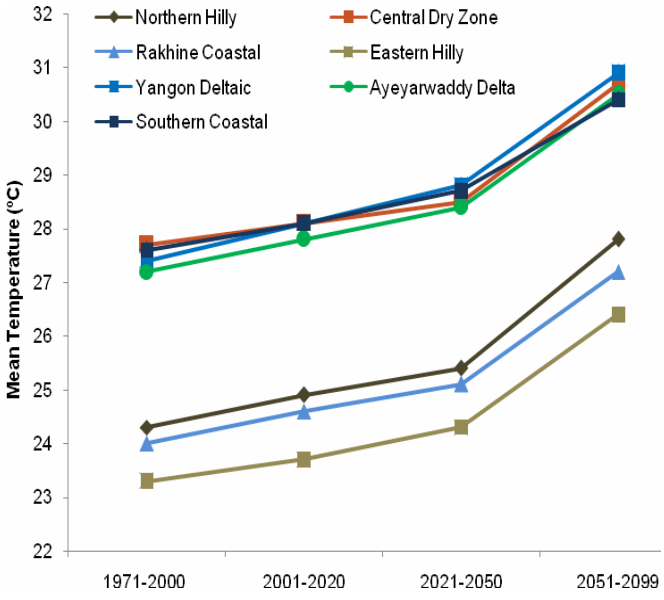


**Fig. 5** Predicted temperature trends for the seven physiographic regions in Myanmar

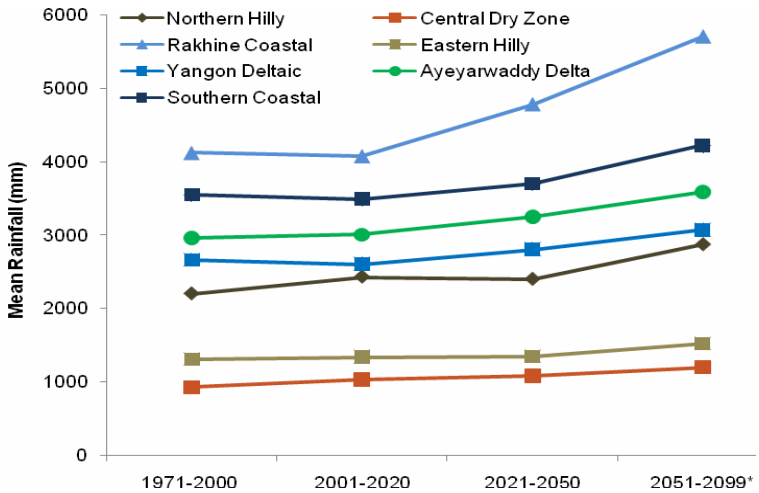


**Fig. 6** Predicted rainfall trends for the seven physiographic regions in Myanmar (NAPA, 2012)

**Table 3** Detailed projected climate change trends across Myanmar for 2001-2100

| Climate change predictions for 2001-2020 | Climate change predictions for 2021-2050 | Climate change predictions for 2051-2100 |
|---|---|---|
| • increase in temperature of 0.4°C to 0.7°C across Myanmar with the Yangon Deltaic region experiencing the greatest increase (0.7°C);<br>• increase in clear sky days in Northern and Central Myanmar exacerbating drought events;<br>• highly variable rainfall changes throughout the country- including large increases in the Northern Hilly region (228 mm per annum) and decreases in the Rakhine Coastal, Yangon Deltaic, and Southern Coastal region (58 mm per annum); and<br>• increase in floods and droughts resulting from variable rainfall conditions. | • increase in temperature of 0.8ºC to 1.4ºC across Myanmar with the Yangon Deltaic (1.4°C) and Rakhine Coastal region (1.2°C) experiencing the greatest increases;<br>• increase in rainfall across the country with the Rakhine Coastal region experiencing the greatest increases (661 mm per annum) and the Eastern Hilly region experiencing the smallest increase (36 mm per annum);<br>• increase in periods of heavier rains; and<br>• longer dry spells. | • increase in temperature of 2.8°C to 3.5°C across Myanmar with the highest increases in the Rakhine Coastal and Yangon Deltaic regions (3.5°C);<br>• weakened monsoon climate supported by decreased cloud coverage;<br>• increase in drought periods across most of Myanmar; and<br>• increase in precipitation with highest increases in the Rakhine Coastal region (1 582 mm per annum) and smallest increases in the Eastern Hilly region (209 mm per annum). |

## 4 Climate change and groundwater sustainability

### 4.1 Impact of climate change on groundwater resources

Global Climate Change has seriously affected Myanmar and, the day time temperature has increased significantly throughout the country along with an increased risk of floods and droughts. Myanmar is also facing water scarcity problems primarily in dry zone, delta areas, hilly regions and certain coastal areas. Because of the drier and hotter weather conditions during the dry season, the shallow groundwater table (seasonal shallow aquifer) is dropping and surface water resources, such as lakes, ponds, rainwater collection tanks, are nearly dry. In addition, infrastructures for water supply such as dams and reservoirs present reduce

because of decreased rainfall input and high evaporation processes. The heavy extraction of groundwater by increased human activities is threatening the sustainability of groundwater resources.

Seawater intrusion is a common problem in coastal zones, especially at river deltas. In Myanmar, there are seven major river outlets. Salt intrusion starts in October and extends to April, and it propagates upstream. The extent of salt intrusion upstream varies depending on the water discharge rates at the outlets. The coastal aquifers of the Ayeyarwaddy Delta are among the most endangered areas because of seawater intrusion.

## 4.2 Impact of climate change on groundwater-dependent systems and sectors

### 4.2.1 Agriculture

Agriculture in Myanmar is extremely vulnerable to climate change. The predicted rise in temperature in Myanmar is expected to have negative impacts on agricultural production and food security. An increase of air temperature will cause the proliferation of weeds and pests, which will reduce yields of crops, such as rice, wheat, maize, soybean, and groundnuts. Furthermore, higher temperatures will increase the incidence of crop diseases, insect pests and rodents. Unexpected changes in precipitation patterns will likely increase the frequency of crop failure, thereby threatening the food security of the country.

Under the predicted climate changes, the highly productive deltaic and low-lying coastal crop cultivation areas in Myanmar will be exposed to increased temperatures, erratic rainfall, droughts, floods and intense rains as well as increased salinity, coastal erosion, and inundation because of sea level rise. The low-lying areas, such as the Ayeyarwady/Yangon Deltaic regions, will become increasingly vulnerable to sea level rises. Changes in crop production in these regions will have a direct effect on the economic conditions of the country, particularly for low-income rural populations who depend on traditional agricultural systems or marginal lands.

### 4.2.2 Energy, transport and industry

The hydropower potential of many of Myanmar's rivers will be significantly affected by increased abnormal weather events, such as intense and erratic rainfall or severe droughts. Intense rains will trigger large-scale erosion and result in siltation and sedimentation of waterways and dams. Such changes will reduce the water-storage capacity of dams and cause structural damage, resulting in increased maintenance and operational costs of the facilities. Transport in Myanmar will also be impacted by climate change. An increase in extreme weather events will cause significant damage to existing transport infrastructure and increase maintenance costs. For example, the cyclone Nargis, which tore across the southern coastal region of Myanmar in 2008, resulted in a loss of US$ 36 million because of road damage/loss (NAPA, 2012). Sea level rise by climate change will also have an impact on coastal transport infrastructure because roads in the path of rising water levels will be vulnerable to collapse triggered by erosion. Industry will also be affected by climate change. For example, the damages/ losses to the industrial sector of Myanmar by the cyclone Nargis was estimated to be US$ 1.814 billion (NAPA, 2012). Furthermore, climate extremes will result in considerable indirect socio-economic effects, such as a decline in employment and industrial productivity, which will likely to restrict the country's economic development.

### 4.2.3 Biodiversity

The effects of climate change on biodiversity are already evident in Myanmar. For example, shifts in the range and migration patterns of certain species of insects, marine/terrestrial mammals, birds and fish have been observed (NAPA, 2012). Furthermore, notable changes in the flowering and fruiting seasons/times of certain plant species have been observed. Changes in temperature and precipitation levels along with extreme climate events (drought and floods) have caused forest dieback, forest conversion to grasslands/ steppes/deserts and increased invasive species/ insect pest distributions. Future climate change will exacerbate these phenomena because of increases in extreme weather events, such as cyclones, droughts, floods and fires, which negatively alter ecosystem functioning and species

compositions, distributions and richness. An increase in extreme heat days and drought periods and rising sea levels will change the chemical composition of water resources, which will likely impact freshwater biodiversity. Similarly, increased sea temperature and changes in seawater chemical composition will modify marine biodiversity, particularly coral reef ecosystems.

## 5 Adaptation to climate change

Myanmar is a country with abundant natural resources, including water resources, and less than 10% of the total water resources are utilized; thus, water scarcity is not currently an issue. However, certain parts of the country, such as the central dry zone, are critical regions that currently experience medium to severe levels of water scarcity. Thus, the need for an adaption plan to climate change becomes more apparent with the increased frequency of water-related disasters, such as floods, droughts, and abnormal temperature.

The water demand in Myanmar will increase in the future with the development of industrial sectors. As the population and urbanization increases, the demand for domestic use will also increase. Consequently, water supply policies and water sharing among the agricultural, power and industrial sectors should be reconsidered. Measures for increasing the urban water supply should also be planned in advance.

The government has emphasized forest conservation and watershed management policies throughout the country to improve water resource conservation. The major activities for adaptation to climate change include (1) controlling mining activities and shifting cultivation within the perimeter of reservoir areas, (2) introducing new cultivation methods, such as terrace farming, firewood plantations for rural people and mangrove forest rehabilitation, (3) watershed plantations for the erosion control and sustainable management of water resources, and (4) estuary/wetland establishment/expansion.

## 6 Technological measures to protect water resources under climate change

### 6.1 Measures to protect groundwater in coastal areas

The government of Myanmar has implemented adaptation measures to protect groundwater resources, particularly in coastal areas. For example, mangrove forests are being extended in marine deposition areas in low land areas to provide storm surge protection and marine ecosystem conservation.

Even with these continuous efforts to protect groundwater resources, a number of technical measures should be implemented for the successful preparation and adaptation to climate change. The technical approaches suggested for groundwater adaptation thus far include enhancing groundwater recharge and storage reservoirs in river basins, replanting mangroves for shoreline protection, constructing flood walls and storm surge barriers, preparing hazard maps, and building capacity for adaptations by all stakeholders. A participatory approach is also important for the sustainable management of groundwater resources. In Myanmar, July has been designated as the Month for Planting Trees via community participation throughout the country. The establishment of water user associations in certain irrigation project areas and the capacity building of farmers for the enhancement of participatory irrigation management are major contributing factors for raising the awareness of groundwater resources.

## 7 Challenges and problems

The water sector faces certain challenges, including unexpected and uneven rainfall patterns, flooding and drought in the main agricultural areas, intensive cultivation activities and illegal logging in watershed areas, and management conflicts and lack of cooperation within agencies. To achieve water sustainability, the water management strategy of Myanmar should be designed to strengthen the legal framework for ensuring the effective and harmonious integration of water resource management. Development and protection activities for water resource should also promote the socioeconomic development of the country by enhancing and consolidating current systems. The water governance sectors should

enhance the organizational capacity and effectiveness of water resource coordination systems for the population to access safe water in a reliable and efficient manner.

In Myanmar, different water resource projects have been constructed throughout the country, such as isolated and multiple reservoir systems, groundwater and river pumping projects, diversion head works and sluice gates for flood protection and saline water intrusion. According to the country's agriculture base economic development policy, infrastructure was implemented for irrigation in conjunction with hydropower generation to promote the industrial and domestic water supply and environmental sustainability (Unpublished departmental report on current state of water in Myanmar, 2016). Although Myanmar currently has abundant water resources, the proper management and a strong policy for the sustainable and continuous development of the economy and environmental conservation are required to secure water resources for future generations. Major issues associated with water security must be addressed, including river water management, flooding, water contamination, and insufficient water governance capacity.

Sedimentation can substantially affect the performance of storage dams and riverbed stages. Transported sediment reduces the storage capacity of reservoirs and increases riverbed levels in the lower reaches of rivers. Mining and deforestation along the upper reaches of river basins also cause serious watershed erosion problems.

Flooding in the downstream regions of rivers produces serious problems. Industrial development and increasing population density will exacerbate water pollution and health risks for people living close to rivers. Thus, careful management of groundwater extraction is also required to avoid exposure to arsenic-rich groundwater.

The lack of a legal and institutional framework also threatens the development of water resources in Myanmar. Although organizational arrangements at the national and provincial levels generally support the achievement of national policies, the water sector in Myanmar has many institutional problems mainly related to (a) weak coordination and collaboration between agencies within the sector and with agencies in other sectors and (b) inadequate communication and coordination between the national agencies and authorities. Acts, laws and regulations related to the water sector should be amended and reviewed with a view towards enacting a unified water resource law to promote a more effective legal framework for coordinating and managing water resources. Other weaknesses in the water sector are limited manpower, scare financial resources, insufficient monitoring facilities, poor systematic record keeping and insufficient regular monitoring and surveillance of water quality. As for water quality control, basic quality standards for drinking water were recommended in 1990, although they have not yet been approved. Joint efforts between the government, local communities and NGOs will be the key to the success of water resource management programs. Moreover, institutional strengthening, capacity building and public awareness are essential elements of such development work.

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