Food and Agriculture Organization of the United Nations

Ministry of Agriculture, Livestock and Irrigation

GOVERNMENT OF THE REPUBLIC OF THE UNION OF MYANMAR

Formulation and Operationalization of National Action Plan for Poverty Alleviation and Rural Development through Agriculture (NAPA)

Working Paper - 3

AGRICULTURAL WATER AND SOIL MANAGEMENT

Yangon, June 2016

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Currency equivalents

(As of October 2014)

Currency		Equivalent
US$1.00	=	979 kyat
€1.00	=	1 225 kyat

Fiscal year

April 1 – March 31

Weights and measures

1 acre (ac) = 0.405 hectares

1 hectare (ha) = 2.471 acres

1 kilogram (kg) = 2.200 pounds (lb)

1 000 kg = 1 tonne (t)

1 kilometre (km) = 0.62 miles (mi)

1 metre (m) = 1.09 yards (yd) or 3.28 feet (ft)

1 square metre (m^2) = 10.76 square feet (ft^2)

1 millimetre (mm) = 0.03937 inches (")

1 cusec (cu ft/sec) = 28.3 L(litres)/s

1 acre-foot = 1 233 m^3

1 km^3 = 810 713 acre-feet

ACRONYMS

ADB	Asian Development Bank
ADRA AIRBM	Adventist Development and Relief Agency Ayeyarwady Integrated River Basin Management
AMD	Agriculture Mechanization Department
CBO	Community-based Organization
CDZ	Central Dry Zone
CIRDAP	Centre for Integrated Rural Development for Asia and the Pacific
CSO	Central Statistical Office
DOA	Department of Agriculture
Danida	Danish International Development Agency
DAP	Department of Agricultural Planning
DAR	Department of Agricultural Research
DWIR	Directorate of Water Resources and Improvement of River Systems
EIA	Environmental Impact Assessment
ESCAP	Economic and Social Commission for Asia and the Pacific
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FDI	Foreign Direct Investment
FFS	Farmers' Field School
FSATG	Food Security and Agriculture Thematic Group
GOM	Government of Myanmar
GRET	Group de Recherche et d'Echanges Technologiques
HDI	Human Development Initiative
ICDP ICIMOD	Integrated Community Development Project International Centre for Integrated Mountain Development
ID	Irrigation Department
IFAD	International Fund for Agricultural Development
INGO	International Nongovernment organization
ITC	Irrigation Technology Centre
IRRI IWMI IWRM	International Rice Research Institute International Water Management Institute Integrated Water Resources Management
JICA	Japan International Cooperation Agency
LIFT	Livelihoods and Food Security Trust Fund
LUD	Land Use Division
MAS	Myanma Agriculture Service
masl	Metres Above Sea Level
M&E	Monitoring & Evaluation
MDG	Millennium Development Goal
MFI	Micro-Finance Institution
MIS	Management Information System
MoAI	Ministry of Agriculture and Irrigation
MOECAF	Ministry of Environmental Conservation and Forestry
MOLFRD	Ministry of Livestock, Fisheries and Rural Development

MOM	Management, Operation and Maintenance
NCEA	National Commission for Environmental Affairs
NGO NWRC	Nongovernmental Organization National Water Resource Committee
O&M	Operation and Maintenance
PACT	Private Agencies Collaborating Together
PPP	Public-Private Partnership
RS	Remote Sensing
TBD	To Be Decided
TCP	Technical Cooperation Programme
UNDP	United Nations Development Programme
UNEP-GEF	United Nations Environment Programme – Global Environmental Facility
UNOPS	United Nations Office for Project Services
USAID	United States Agency for International Development
VDC	Village Development Committee
WB	World Bank
WDC	Water Distribution Committee
WFP	World Food Programme
WRUD	Water Resources Utilization Department
WUG	Water User Group
YAU	Yezin Agricultural University

1. INTRODUCTION

This study, undertaken in September to October 2014, is one of a number of technical studies carried out during Phase I of the Food and Agriculture Organization of the United Nations' (FAO) formulation of the National Action Plan for Agriculture (NAPA) for Myanmar. The objective of NAPA, as a component of the National Strategy on Poverty Alleviation and Rural Development (NSPARD), is poverty alleviation and rural development through agriculture.

The Terms of Reference (ToR) for the study required the consultant to review all relevant aspects of activities related to water use for agriculture, including water capture, storage and utilization (including multi-use systems) as well as soil conservation and management practices, with emphasis on community-managed and controlled resources.

A desk study of relevant documents was carried out, followed by meetings and focus group discussion with a range of key stakeholders, particularly government entities, farming communities and the private sector in the different agro-ecological zones (AEZs). Visits were made to irrigation schemes of various types, water control and storage structures including flood control embankments, as well as areas with saline and sodic soils and soil conservation activities in the regions of Mandalay, Sagaing, Bago, Yangon and Ayeyarwaddy, and in Shan State. The findings of these interactions together with a detailed literature review on agriculture and natural resources, policies, strategies, programmes and projects related to agricultural water and soil management in Myanmar have been used in the preparation of this document. Key opportunities, constraints and possible interventions and investments are identified. The references used in compiling this report are listed in Annex 1.

2. BACKGROUND

The Government of Myanmar (GOM) places the highest priority on the development of the agriculture sector, which generates 43 percent of the GDP; the sector is perceived as the basis for food security, increased employment and export promotion. The primary means of improving food crop production will be effected by extending and upgrading irrigation systems. Overcoming constraints such as deficient flood control structures, inadequate drainage, poor salinity control measures and soil erosion is also vital.

Myanmar can be divided into five major topographic and climatic zones: the mountainous region, the Shan Plateau, the Central Dry Zone (CDZ), the delta region and the coastal region. The mountainous region covers the north and west of the country, bordering India, and is characterized by high mountains (up to 5 800 metres above sea level), dense forest and uplands. To the east is the Shan Plateau consisting of rolling hills and uplands at an elevation of about 2 000 metres. The population density in the mountainous region and the Shan Plateau is low and largely comprises ethnic minorities. Both regions are characterized by low levels of development, poor infrastructure and poor communications. Further south is the CDZ, with the lowest annual rainfall, an extended dry season and infertile, sandy soils, but with the second-highest population density in Myanmar. The delta region at the confluence of three major river systems, the Ayeyarwaddy, the Sittaung and the Thanlwin, is a vast area of fertile soils. It has the highest population density, highest land productivity, fairly high rainfall, relatively flat topography and provides an excellent environment for agriculture, especially rice production. The coastal region runs along the eastern side of the Bay of Bengal and the Andaman Sea, bordering Thailand. The southern portion of this region has the highest annual rainfall in Myanmar and is well suited to growing perennial crops such as coconut, oil-palm and rubber.

Myanmar's climate is tropical monsoon. It can be divided roughly into three main seasons, summer from March to mid-May, the hot rainy months of the southwest monsoon from mid-May to late October and the winter cool season from November to the end of February. Rainfall varies from highs of 4 000-6 000 mm annually in the coastal regions and in the mountains of Rakhine and Tanintharyi, to as low as 600-1 000 mm in the CDZ.

Average annual water resources are estimated to be some 1 500 km^3, with 1 000 km^3 coming from surface water and the remaining 500 km^3 from groundwater. However, if the base flow of the rivers is excluded from calculations, the total internal renewable water resources are just over 1 000 km^3/year. The monthly distribution of river flows closely follows the pattern of rainfall, with about 80 percent of flow during the monsoon season (May-October) and 20 percent in the dry season (November-April).

Because of the rainfall and hydrological patterns, the need for irrigation is highest in the CDZ, while in the Delta the main concern is drainage and flood protection. Land degradation in Myanmar is caused by water erosion, wind erosion, soil fertility depletion, salinization, alkalinization and water logging. Land degradation, particularly soil erosion, is an increasing problem in upland agricultural areas and dry zones due mainly to deforestation, poor agricultural practices, overgrazing and shifting cultivation, all of which are exacerbated by the increasing population. Saline, alkaline, acid-sulphate and other problem soils occur mainly in the CDZ and the Delta and it is estimated that they account for over 5 percent of total cultivable land in Myanmar.

2.1. Sector history

Water resources

Myanmar has abundant water resources and there is considerable potential for further water resource development, but dangers include increasing competition between users (industry, hydropower, urban water supply and agriculture), overexploitation in the dry season and pollution from mining and industry. Also, inappropriate agricultural practices and the loss of forest cover are leading to siltation of reservoirs and riverbeds and to more and faster runoff causing greater variations in river flows. Hydropower has been steadily increasing its water usage as Myanmar seeks to expand economic productivity, raise incomes and alleviate the acute poverty of the majority of the population. The retention of large volumes of water by hydropower dams, several of which are under construction or planned on the Ayeyarwaddy, Chindwin, Sittaung, and Thanlwin, will affect river flows, especially during the dry season. However, it appears that their cumulative effect has not been assessed, nor have modelling studies been undertaken.

Despite groundwater resource development spanning at least the past four decades, there is scant published information on hydrogeology and groundwater resources. Unpublished works by Groundwater Development Consultants (1984) and Drury (1986)[1] are the most significant. An ESCAP[2] study in 1995 found that most groundwater in the CDZ was of low to moderate salinity with a tendency to be sodic. Arsenic in groundwater is a particular hazard in the Ayeyarwaddy Delta, but studies by the Water Resources Utilization Department (WRUD) indicate that there is a low risk in the CDZ of arsenic exceeding the World Health Organization (WHO) drinking water guideline value of 10 μg/litre.

There is considerable potential for further development of water resources and related infrastructure, but a planning and institutional framework for overall water resource management, taking full account of long-term river flow data and aquifer recharge rates, is vital to ensuring the sustainability of water resources.

In recent years, slow progress has been made towards establishing a framework for overall water resource management. In 2003 the Ministry of Agriculture and Irrigation (MoAI), in cooperation with UNESCAP and FAO, launched the 'Myanmar Water Vision' and this was followed by the establishment of the National Water Resources Committee (NWRC) in 2005. In May 2013 a Memorandum of Understanding (MoU) was signed between the Netherlands and the GOM) on cooperation in the field of integrated water resources management (IWRM). In addition, the World Bank started preparation of the Ayeyarwady Integrated River Basin Management Project (AIRBM) in early 2014. Its objective is to strengthen integrated, climate-resilient management and development of the Ayeyarwaddy River Basin and national water resources.

[1] The most significant information sources are two unpublished works: (1) Drury, L.W. 1986. *An assessment of the hydrogeology and geology in the Dry Zone, Central Burma.* Australian Development Assistance Bureau and Ministry of Agriculture and Forests, Union of Burma. Draft report. (2) Groundwater Development Consultants. 1984. *Burma Umbrella Project: Groundwater exploration and pilot development sub-project.* Final report. 3 Vols., Cambridge, UK.

[2] ESCAP. 1995. *Assessment of water resources and water demand by user sectors in Myanmar.*

Irrigation

Irrigated agriculture in Myanmar dates from the ninth century when low diversion weirs on the tributaries of the middle Ayeyarwaddy and small tanks were constructed to provide security for the monsoon season rice crop. In 1917 the Irrigation Branch was established in the Public Works Department and gradually began to replace the earth diversion weirs of the traditional systems with more stable masonry or concrete structures, replace simple canal off-takes with gate structures and line some canals. After independence in 1948, the Irrigation Branch continued maintenance of existing irrigation networks and also embarked on new projects in various parts of the country. In 1972 the Irrigation Department was formed to coordinate the development and management of water resources for irrigation. By 1989 about 1 million ha of land were under irrigation, but most irrigation effectively remained supplementary to monsoon rains.

In the early 1990s the government embarked on an ambitious irrigation expansion and land reclamation programme based on:[3]

a. The construction of new dams and reservoirs along the main river;

b. Pumping of water from rivers, streams and groundwater for irrigation;

c. Storage and utilization of runoff from watersheds, including diversion of water from streams during the monsoon season into adjacent ponds; and

d. Rehabilitation of existing reservoirs to increase storage capacity and efficient delivery of irrigation water.

With the increasing concern for food security in the CDZ, resulting from the unpredictable and variable rainfall and the extremely limited options for gravity irrigation, the WRUD was established in 1995. Since then it has been responsible for all pumped irrigation projects, whether from surface water sources or groundwater. These now represent approximately 40 percent of the land equipped with irrigation facilities in the country.

By 2001 it is estimated that the total irrigated area in Myanmar had reached 1.9 million ha. This increased to 2.3 million ha in 2009/2010, with nearly 28 percent of the area double cropped, but by 2012/2013 the area under irrigation fell slightly to 2.1 million ha, with about 23 percent of the area double cropped.

All new projects relying on dam construction are now multipurpose projects. Besides storing water for irrigation, they may assist in flood control, provide domestic water for urban areas or provide hydroelectricity. The priority for multipurpose projects with hydropower is an indicator of the expanding demand for energy. In some cases, an irrigation scheme is of secondary importance and has only been partially developed.

Flood control and drainage

Probably of greater importance historically than irrigation has been the provision of water control infrastructure to prevent flooding, improve drainage and reduce saltwater intrusion, especially in the fertile Ayeyarwaddy and Sittaung delta areas. Construction of embankments for flood protection in the Ayeyarwaddy Delta started in the 1880s. By 2012 nearly 700 000 ha of good cropland was protected by over 2 000 km of embankments and drainage channels,

[3] MoAI. 2003. *Outline of the Irrigation Department.* Yangon, June 2003.

including sea dykes in coastal areas to protect the land from saltwater intrusion. These embankments protect nearly 30 percent of the 2.4 million ha of agricultural land in the delta. Some protected areas are irrigated during the summer using the tidal effect. Channels that provide drainage at low tide are used as irrigation canals during high tide, with the direction of flow controlled by sluice gates. River embankments are also found in the upper Ayeyarwaddy River Basin, especially near Mandalay, where adverse land slopes leave land prone to flooding. Many of the structures in the delta were badly damaged by Cyclone Nargis in 2008, which affected 50 townships, mainly in Yangon and Ayeyarwaddy regions. Rehabilitation is still not complete leaving some of the most productive parts of the country vulnerable to floods.

Water control infrastructure also includes about 180 000 ha of aquaculture ponds, primarily in the Delta Region. This is a growing industry with ample potential for expansion and opportunities for foreign exchange earnings.

Soil erosion and land degradation

A priority environmental concern is land degradation including soil erosion, decline of soil fertility and increase of land salinity. Land degradation, particularly soil erosion in upland agricultural areas and dry zones, is an increasing problem in Myanmar.

The main causes of land degradation include deforestation, poor agricultural practices, overgrazing and shifting cultivation, all of which are exacerbated by the increasing population, particularly in the upland areas. Between 1980 and 2008, the upland population increased by 7.0 million to 17.5 million, accounting for about 30 percent of the total population. This has resulted in a large expansion of cultivated areas and multiple cropping has become more common. To sustain agricultural productivity in upland areas, targets have been set for the reclamation of sloping agricultural land and slash-and-burn areas. Despite such initiatives, the land rehabilitation programme has lagged behind expansion of areas under cultivation. While the total crop area increased from 10.5 million ha to 22.3 million ha between 1985 and 2008, the percentage subject to rehabilitation measures steadily dropped to only 3 percent in 2008. Villagers often recognize that wind and water erosion are occurring on their land but do not know what to do about it. Various soil conservation and land rehabilitation programmes have been initiated through the Ministry of Environmental Conservation and Forestry (MOECAF) and the MoAI, particularly in Shan and Chin states and in the CDZ, in some cases with support from agencies such as UNDP, FAO, UNEP and ICIMOD.

From 1994 to 2001 the United Nations Development Programme (UNDP) implemented grassroot-level activities under the Human Development Initiative (HDI) framework. This included tackling soil and water conservation on hillsides and cultivated lands in the CDZ and watersheds of Shan State. As far as possible, the project addressed the problem within target villages by taking a watershed or catchment area approach. Soil conservation measures carried out in project villages included construction of spillways, bench terraces, soil sedimentation bunds and check dams to protect village range land and farmland within project villages. However, as participating villages were selected on the basis of poverty status, adjoining villages located in the same catchment were often excluded. As a result, a comprehensive catchment-wide approach proved impossible in most areas.

Problem soils

Government data indicate that problem soils occupy an area of nearly 1 million ha, accounting for 5.3 percent of the total cultivable land area. Of this about 0.3 million ha are acid-sulphate soils, degraded soils, peat soils and swampy soils, while saline and alkaline soils accounted for the remaining 0.7 million ha.

Waterlogging can cause soils to become saline and/or sodic. This is a particular problem within irrigation schemes in parts of Mandalay and Bago regions, where vertisols (heavy black clays) prevail and inadequate drainage has been provided and, also, in some areas where water tables are shallow and the soils' internal drainage capacity is insufficient to remove excess water. Using poor quality groundwater for irrigation can also lead to soil salinity/sodicity.

In the Delta, seawater is penetrating ever deeper especially in the dry season, again leading to soil salinity. Also, acid-sulphate soils have developed in some coastal sediments where naturally occurring pyrite (FeS_2) has oxidized when the soils were drained to make way for agriculture.

Salinity risk assessment and monitoring are needed to gauge the magnitude of the problems and to develop strategies and measures to prevent soil from being degraded. The Land Use Division (LUD) under the Myanmar Agriculture Service (MAS) has overall responsibility for research on soil problems. In the Delta Region, LUD has experimented with the application of lime to saline soils on experimental plots and in the Dry Zone experiments have been carried out with the use of gypsum on sodic soils. However, the LUD but has insufficient capacity to monitor degradation of soils adequately and plan the mitigation measures required.

2.2. Overall sector scope, status and performance

Irrigation

Since the early 1990s the GOM has made considerable efforts to increase water utilization in agriculture. By 2012, nationally a total of more than 300 dams and weirs had been constructed, over 300 river pumping stations had been built and some 8 300 tubewells had been installed (FAO 2013), a considerable proportion of them in the Dry Zone. About 44 percent of irrigated land is served by gravity systems from dams, tanks and river diversions, 38 percent by river-pumped systems, 6 percent by groundwater-pumped systems and 12 percent by water harvesting and other methods. Nevertheless, irrigation development in Myanmar has fallen behind that of neighbouring countries. At present about 2.1 million ha of a potential 10.5 million ha are estimated to be served by irrigation systems.

Most large schemes are funded and operated by the GOM, with a few receiving some support from donors. The main irrigation infrastructure, including dams, weirs, river/groundwater pumps and the water distribution system to farm level, is constructed, operated and maintained by the Irrigation Department (ID) or the WRUD. Beneficiary farmers are expected to construct and maintain tertiary-level canals and field ditches. Many irrigation schemes function below their potential due to inappropriate operation of reservoirs, poorly developed systems and inadequate management, operation and maintenance (O&M). Farmers frequently fail to construct the field-level channels and, even where they exist, they are often poorly maintained. With current low farm-gate prices for rice and lack of farmland ownership, there is little incentive for farmers to develop them on their own. Improvements to

irrigation structures, drainage, land levelling, and operation and maintenance, combined with a change in cropping patterns to non-rice crops, would enable cropped areas to be extended and cropping intensities to be increased in existing schemes.

Small-scale schemes have sometimes been developed as a component of broadly-based livelihood programmes with assistance from donors such as UNDP or from NGOs. Many individual farmers, particularly in the CDZ and Delta areas, own or rent low-lift diesel pumps to irrigate from rivers, groundwater or, in some cases, the canals within large irrigation schemes because their land is out of command. Sprinkler and localized irrigation has been developed only on a pilot basis by the GOM. NGOs have financed a few small sprinkler systems and drip irrigation, and some private companies and better-off farmers use sprinklers. Due to their technical complexity and the high investment required, most farmers are still reluctant to try such technologies.

Flood control and drainage

Flood control and drainage infrastructure will become increasingly important in the presence of global climate change impacts. Farmers observe that weather patterns are increasingly difficult to predict, with drought one year and flooding the next. Most formal assessments suggest that climate change will affect Myanmar significantly. Major expected changes include rising temperatures, higher rainfall and a possibly a shorter rainy season, which in combination will contribute to a considerable increase in flooding. Rising sea levels along the coast are likely to compound these problems by aggravating saltwater intrusion and soil salinity in the coastal areas and river deltas. Risk reduction will require household as well as system-level investments in diversification and water control to manage increasingly unpredictable swings in seasonal rains and drought.

In the coming decades river bank protection and improvements to the 2 000 km of flood protection embankments, including raising their height, will become increasingly important. Also, many of the sluice gates in embankments are in poor condition and need to be repaired or replaced.

Soil erosion

About 10 percent of total cultivated land in the country is estimated to be vulnerable to severe soil erosion, with Shan State, Chin State and Sagaing Region amongst the most badly affected areas. Degraded farmland, as a percentage of total cultivated area, was estimated at 33 percent in 2008. The GOM's capacity to implement soil and water conservation measures and to reclaim degraded land is limited by insufficient expertise and funding. Whilst donor-funded projects have emphasized the need for a catchment-wide conservation approach, in practice resources have been spread too thinly and the tendency has been to work with just the poorer villages, excluding better-off villages in the same catchment.

In Myanmar the emphasis is still on physical, rather than vegetative, techniques for control of runoff and erosion. Techniques such as terracing often do little to increase production or incomes and have a high labour requirement. Food or cash-for-work has frequently been used in donor-funded projects where these measures have been employed. In drier areas such as the CDZ, however, where it is more difficult to implement vegetative methods, physical methods may be needed to help plants to become established and cover the ground quickly. As a result of past soil conservation projects by agencies such as UNDP and FAO, extension staff and many farmers and in the CDZ are already familiar with physical techniques that

have relatively low labour requirements such as contour ploughing, contour earth or stone bunds, and 'trash lines' formed from the residues of past crops, and the methods are commonly used.

Due to inadequate budgets and staff, soil conservation activities on agricultural land undertaken by the LUD of the MoAI and the MOECF are mainly limited to small demonstration plots, sometimes carried out in cooperation with local farmers. Field days for farmers are held on these plots occasionally, but government officers complain that farmers are reluctant to copy the techniques unless paid. This is particularly evident in the watershed surrounding Inle Lake in Shan State, an important tourist resource, where there is considerable concern about high siltation rates. The main emphasis of the MOECF has been on tree planting on the surrounding slopes. However, much of the watershed is agricultural land, including areas of shifting cultivation, and in these areas efforts to control soil erosion appear to be limited entirely to demonstration plots. The International Centre for Integrated Mountain Development (ICIMOD) has recently started funding soil conservation activities in this area, again mainly in the form of demonstration plots.

Problem soils

Saline and sodic soils are a problem on sections of a number of large government irrigation schemes and also some small groundwater systems established by NGOs. On the large gravity schemes they result from poor drainage. In groundwater systems they come from the use of poor quality groundwater, sometimes combined with saline or sodic soils. Once land has become saline, or worse still sodic, reclamation is difficult, expensive and can take several years, requiring provision of good drainage and regular applications of lime or gypsum. If the problem results from use of poor quality groundwater, farmers have to revert to rainfed cropping and rely on rainfall to leach the soils.

2.3. Contribution to overall economy and livelihoods

Agriculture is the backbone of Myanmar's economy, but despite its enormous potential, it has underperformed over the past 50 years. Given that over 70 percent of the population lives in rural areas and primarily works in agriculture, low farm productivity translates into high rates of poverty and food insecurity. A primary means of improving food crop production will be through extending and upgrading irrigation systems and, in particular, improving the availability of irrigation for crops in the dry season. The Delta area, which includes the Ayeyarwaddy, Yangon and Bago regions, has some of the most productive cropland in Myanmar. It produces 60 percent of the country's total rice crop. Rehabilitation and upgrading of flood control structures and drainage works are important to protect the area from floods and saltwater intrusion.

Soil erosion and land degradation in hilly and mountainous areas need to be tackled to improve land productivity, to protect valuable resources such as reservoirs and lakes and to reduce the silt load in rivers. The Ayeyarwaddy River, for example, has the fifth highest sediment load of any major river in the world and many believe that the rate of sedimentation is rapidly increasing as a consequence of deforestation in the river's fragile upstream landscape and widespread land-use changes across the basin. Deposition of silt in riverbeds raises the risk of flooding in the rainy season. In the low flow season (November to May), heavy, shifting sediment deposits now hamper navigation as the river depth is insufficient for use by large or heavily loaded vessels.

3. SPECIFIC ASPECTS OF AGRICULTURAL WATER AND SOIL MANAGEMENT

Agriculture, including livestock, fishery and forestry, is the most important sector of the national economy. Agriculture and rural poverty are closely linked. Development of the agriculture sector is the key to poverty reduction and water is the most fundamental requirement for agricultural development. Threats to agriculture include disruption to annual river flow patterns, competition for low flows in the dry season, flooding, soil erosion and soil problems such as salinity and sodicity.

3.1. Water resources, irrigation and flood control

Water resources

Myanmar has abundant water resources with significant groundwater and six major river basins. However, roughly 80 percent of freshwater flows during the May-October monsoon season, with only 20 percent available during the November-April dry season. Water scarcity is a particular challenge in the CDZ, and a seasonal constraint elsewhere, particularly in parts of Bago and Yangon regions and in Kachin and Shan states.

An Agricultural Water Resource Study, carried out under the FAO Agricultural Sector Review (2004), estimated the total annual runoff within Myanmar at 875 km^3. The total storage capacity of dams was estimated to be 15.5 km^3 in 2005. In addition, good quality groundwater, suitable for both irrigation and domestic use, can be found in the Alluvial and Irrawaddian aquifers (see Map 6, Annex 3). Potential renewable good quality groundwater resources were estimated to be 28.3 km^3 – only 1.3% of the annual groundwater storage capacity. This is much less than the estimated overall groundwater potential of 500 km^3 published by ESCAP (1995)[4]. Groundwater from Peguan, Eocene and Plateau limestone aquifers tends to be saline and can be sodic. It is sometimes used for domestic purposes, but is often unpalatable, and if used for irrigation is likely to cause soil problems. Also, arsenic is found in some groundwater particularly in the Delta region, but occasionally in other parts of the country.

A study of the CDZ by the International Water Management Institute (IWMI)[5] in 2013 agrees that groundwater is a more moderate resource than estimated in some earlier surveys, with about 4.7 km^3/year available – equivalent to approximately 50 percent of the current surface water storage and less than 2 percent of the total surface water resource. The IWMI report states that, whilst extremely important for the CDZ, groundwater must be planned and developed carefully to ensure availability in the long term. Nevertheless, it estimates that annual groundwater recharge is sufficient to irrigate a further 110 000-300 000 ha in the CDZ.

The depths of aquifers can vary considerably. For example, the Irrawaddy aquifer is found at depths of up to 350 metres in Magwe Region, but is far shallower in Sagaing Region where maximum depths are only 120 metres. According to the Agricultural Water Resource Study, there is evidence that the Ayeyarwaddy Delta is underlain by a series of both deep and shallow freshwater aquifers. Among them is probably the "thickest artesian alluvial aquifer in

[4] ESCAP. 1995. *Water resources and water demand by user sector in Myanmar.*
[5] IWMI. 2013. *Water resource assessment of the Dry Zone of Myanmar.* Final report. Livelihoods and Food Security Trust Fund /UNOPS.

the world".[6] It extends across the delta from Pathein to Yangon at a depth of 366-1 890 metres. If developed, free-flowing water could be used to irrigate a large portion of land in this area, especially during the dry season. Energy costs are often a significant factor in water extraction and delivery. If good quality artesian water is available in aquifers underlying the delta, relatively low cost development could raise levels of crop production in the area significantly. However, care must be taken as unrestricted groundwater extraction could result in land subsidence and saltwater intrusion.

Groundwater is being widely promoted as a solution to water resource issues, particularly in the Dry Zone. However, comprehensive data on the locations, depths, extent and quality of suitable aquifers have not been adequately compiled and the risks of unsustainable development are high. There is an urgent need to complete and update past surveys and provide detailed hydrogeological and hydrochemical maps using modern techniques of remote sensing and GIS where applicable. In particular, further work is needed to determine the extent and prevalence of salinity and arsenic. In order to ensure the recharge of groundwater aquifers, surface water has to be managed along with groundwater in an integrated way.

Accelerated economic development, prompted by Myanmar's strategic location and opening up to foreign investment, will intensify urbanization and industrialization. In turn, this will intensify the competition for water resources particularly in the dry season and, in the absence of strong environmental legislation, further pollution of rivers, groundwater and other waterbodies. To minimize adverse effects on water resources, Myanmar must ensure sustainability through appropriate legislation and the establishment of a sound institutional management system.

Water rights will become increasingly important as successful small-scale borehole or river extraction development occurs. It will be necessary to clearly define the conditions under which individual landholders are able utilize water beneath or adjacent to their holdings. Here a balance needs to be struck between overexploitation, as is occurring in Bangladesh as a result of weak or absent controls, and the restriction of development arising from time-consuming and complex approval measures.

At present inadequate water sector statistics and data are a serious constraint to water resource planning and coordination among water users and the different agencies dealing with water resource development. A comprehensive analysis of the water sector, both surface- and groundwater, and the development of a coherent development strategy to guide water resource investment in the future are urgently required to avoid piecemeal development with limited impact and high risk of unsustainable practices. There is an urgent need to establish an effective nationwide water-related data management system that comprises contemporary monitoring networks supported by appropriate data collection protocols and modern, easily accessible databases and analysis tools.

Efforts to establish a planning and institutional framework for overall water resources management have made slow progress. In 2003 the MoAI, in cooperation with ESCAP and FAO, launched the 'Myanmar Water Vision' which states that *"By the year 2030, the country will have an attainment of sustainability of water resources to ensure sufficient water*

[6] Economic and Social Commission for Asia and the Pacific (ESCAP). 1995. *Assessment of water resources and water demand by user sectors in Myanmar.* United Nations.

quantity of acceptable quality to meet the needs of people of the country in terms of health, food security, economy and environment". As a follow-up activity, Strategic Planning and Management (SPM) was launched in 2004. The outcome of SPM was the establishment of an apex body the National Water Resources Committee (NWRC) in 2005. It focuses on the following priorities:

a. Harmonizing the relationship among water-related agencies;

b. Establishment of rules for water resource management;

c. Establishment of a pilot river basin management study; and

d. Enhancement for the participation of all the stakeholders.

A Water Resources Master Plan is needed, based on the concept of integrated water resource management. To this end, an Integrated Water Resources Management (IWRM) strategic study is being carried out by the Netherlands.

In May 2013 an MoU on cooperation in the field of IWRM was signed between the Netherlands and the GOM. This includes:

a. An IWRM data collection project;

b. Capacity building at universities and training facilities, through the Netherlands Initiative for Capacity Development in Higher Education;

c. Knowledge transfer and advice provided by experts;

d. A strategic study on the implementation of IWRM; and

e. The identification of possibilities for concrete and sustainable IWRM projects.

A capacity-building programme has started, supporting Myanmar in building up knowledge on water management. Also, assistance and training have been provided to collect data necessary for the modelling of rivers and waterways. A number of workshops and training sessions have been held with relevant organizations and, in particular, with the Ministry of Transport, MoAI and MOECF. A consortium of Dutch Companies has been working together with local counterparts on a strategic IWRM study in Myanmar that will be finalized in November 2014.

In addition, the World Bank is supporting the AIRBM through a loan of US$100 million. Preparation of this project started in early 2014. Its objective is to strengthen integrated, climate-resilient management and development of the Ayeyarwaddy River Basin and national water resources. It will be implemented by the Directorate of Water Resources and Improvement of River Systems (DWIR) under the Ministry of Transport. Although one of the main aims appears to be improvement of navigation on the Ayeyarwaddy, the data collected and water resource planning aspects will benefit all water users, including those involved in agriculture.

The first phase aims at developing the institutions and tools needed to implement integrated river basin management, and deliver related livelihood benefits from enhanced navigation, hydrometeorological warning and advisory services. It will include institutional, legal and regulatory reviews and reforms relating to water resource management. An Ayeyarwaddy Integrated River Basin Master Plan and Decision Support System will be developed. Activities will include groundwater and sediment surveys, and upgrading of

hydrometeorological observation, data management and communications. Guidance will be provided on investment options, particularly priority investments that may be financed under future phases of the project, while also developing the tools and processes needed to ensure the government has ongoing capacity to plan and manage its water resources.

Irrigation

The government gives irrigation development a high priority in order to increase crop yields and cropping intensity. This is reflected in the large share of the development budget devoted to the construction and maintenance of irrigation schemes under current and proposed plans for the agriculture sector.

The MoAI aims to increase irrigation coverage to about 25 percent of the total area under cultivation through: (i) construction of new dams and weirs; (ii) renovation of existing reservoirs to raise storage capacity and rehabilitation of existing government-maintained and village irrigation works, with a greater emphasis on efficient delivery of irrigation water and on-farm water management; (iii) improved management and storage of water from streams and surface runoff during the rainy season; (iv) construction of dams and sluices to impound backwaters of the Ayeyarwaddy and Chindwin rivers during floods for late-rain cropping; (v) lifting water from rivers and streams using pump irrigation; and (vi) efficient use of groundwater.

The thrust to move forward with irrigation developments as quickly as possible has compromised the quality and sustainability of some projects implemented in the last 15 to 20 years. Inadequate feasibility studies have led to inflated figures for potential command areas and insufficient attention being paid to constraints such as water and soil quality. Projects have been significantly affected by shortage of funds for both construction, compromising quality, and for the management, O&M of the finished scheme. Revenue from water charges applied by ID and WRUD schemes are rarely sufficient to cover the cost of project management.

Reported problems with irrigation systems include inappropriate design that prevents adjustment of water supply according to variations in demand over seasons, incomplete tertiary canals and on-farm networks, unlined canals with high seepage rates, lack of land levelling, inappropriate crop choice and irrigation methods for the type of soil, and lack of maintenance and monitoring. Soil salinity and sodicity due to waterlogging or from the use of poor quality groundwater for irrigation have reduced yields considerably in parts of a number of schemes, particularly in the CDZ. In some cases, land that produced reasonable yields under rainfed conditions has been abandoned or produces very poor crops as a result of the introduction of irrigation.

Improved engineering, technical and extension support, changes to crop selection and an increase in farmer involvement have been proposed as approaches to improve the performance of irrigation schemes. With improved management and a change in cropping patterns to non-rice crops it would be possible to expand the cropping areas and cropping intensity. This may necessitate minor structural alterations to the irrigation schemes to improve water control and drainage and, in some areas, land levelling is needed.

Under current programmes little attention is paid to irrigation efficiency and to water and energy productivity. Water is often inefficiently transported and applied, resulting in irrigation efficiencies as low as 21-34 percent. As farmers pay a water tax based on area,

rather than the volume of water used, they have no incentive to use water efficiently. Also, the requirement still exists in some areas for farmers to grow paddy twice a year. This places a very heavy demand per hectare on water supplies and limits the irrigable area for a given water supply. Calculations presented in the FAO Agricultural Sector Review (2004) suggest that it is possible to double the gross margin per unit of water supplied through the selection of optimum cropping patterns.

Management of irrigation operations has traditionally been a government responsibility, under the control of the ID or WRUD. This has led to considerable inefficiency in operations, as decisions tend to be taken on a top-down basis, with relatively little reference to local needs and requirements. Nor is this approach likely to ensure the active support of the beneficiary farmers in the maintenance of infrastructure and equipment. The existing style of water management is a serious constraint to maximization of water-use efficiency. For example, farmers make little or no profit on paddy crops at present and are often reluctant to grow a dry season crop, preferring to leave land fallow. Cropping intensities under irrigation will only increase if farmers are allowed to respond to market demand and price when deciding on crops to grow.

Most irrigation schemes have Water User Groups (WUGs), each with 10 to 20 members, and based on lower-level hydraulic units. The WUGs are responsible for repair and maintenance of the field channels and tertiary canals and ensuring the fair distribution of water. In some schemes the WUG leaders are expected to collect water taxes from farmers. The WUGs are under the control of the Township Agriculture Supervision Committee or a Village Tract Committee. The committees are headed by the township or village tract chairperson and members include representatives of the ID, LUD WRUD, MAS AMD and, in some cases, farmer representatives.

No policy, strategic or institutional framework exists that sets out the rights and obligations of irrigation stakeholders and WUGs. In the case of complaints farmers often approach the field staff of the ID or WRUD as individuals.

The amount of water tax collected has reportedly declined every year. Collecting water taxes is difficult because of fragmented ownership, a lack of clarity over titles and no system of formal rules and sanctions that govern WUGs. In addition, sanctions are difficult to apply partly because field-to-field irrigation makes it difficult to isolate an individual farmer, partly because of the lack of a legal framework and partly because government policy emphasizes food security policy and so officials are reluctant to cut off irrigation supplies.

Projects supporting farmer-managed irrigation systems, or those jointly-managed with a government agency, tend to have lower unit investment costs and perform better than projects with systems managed solely by a government agency. There is an obvious need to strengthen farmer-agency relationships in irrigation, based on their complementary roles in system management and mutual accountability. An important component of this is the capacity building of WUGs and farmers. Key constraints include the lack of an enabling environment, which normally requires: (i) a stakeholder dialogue and consensus building process; (ii) an enabling legal framework in which the legal status, membership, rights and responsibilities of members are clearly stipulated; and (iii) a capacity-building and support programme.

About 40 percent of the irrigated area is irrigated through pumping, but diesel or petrol pumps are used in many cases because of the limited availability of electricity. These are

much more expensive to operate than electric pumps and represent yet another disincentive to farmers to investing in increased food crop production.

In Myanmar limited attention has been given to small-scale water extraction, using such technologies as village or group boreholes and low lift river pumps. Many small diesel pumps are owned or rented by farmers but, with low farm-gate prices yet constantly rising fuel prices, there is little incentive for them to increase their production. The low cost of these approaches and the tendency of farmers to utilize such sources primarily for supplementary irrigation makes these technologies attractive not only from the perspective of poverty reduction but also efficiency of water use.

In the CDZ, many reservoirs, ponds and tanks have been constructed by the ID. These comprise either earth embankments or excavated cavities in the ground to store water. Some provide water only for domestic use or livestock, but others are also used for small-scale irrigation. In recent years, NGOs such as ActionAid, ADRA and Proximity have been working to construct and rehabilitate these structures. The exact locations of many are not recorded, but regional offices of the MoAI have estimated the total storage capacity to be nearly 9 km^3 − about 8 km^3 in 60 large reservoirs and 1 km^3 in some 2 000 small reservoirs, tanks and ponds.

With irrigation, farmers are willing to invest more in the use of modern inputs, labour and services, taking into account the reduced climatic risks such as drought and flooding. Indeed irrigation *per se* without the other key elements of high productivity will not guarantee crop yield increase. Irrigation pumps are very popular in several villages. Farmers identify pumps as an efficient way to overcome the lack of hard irrigation infrastructure such as dams and at the same time to reduce the likelihood of production lost due to drought and in some cases flooding. Pumps are used to drain water from flooded fields. Farmers also use the investment during the dry season, thus increasing the possible number of harvests per year as well as crop productivity.

The use of agrochemicals is increasing with the intensification of agricultural productivity, particularly in irrigated areas. In the future, the government should seek to minimize the negative impact of agrochemical use on water resources, particularly irrigation water, by taking measures through law enforcement. Moreover, the government should encourage and develop community education programmes for the utilization of economical and low-impact use of agrochemicals to mitigate water quality deterioration.

Flood control

Much of the low-lying Delta Region is subject to flooding, storm surges and salinity intrusion, resulting in crop losses and reduced yields. In 2008, over 100 000 people died and as many as 2.4 million people were affected by Cyclone Nargis. Many flood, drainage and salinity control structures were damaged and some have yet to be repaired or replaced.

Most formal assessments suggest that climate change will affect Myanmar significantly and farmers say that weather patterns are increasingly difficult to predict, with drought one year and flooding the next. Major expected changes include rising temperatures and higher rainfall, but possibly a shorter rainy season. This will contribute to greater frequency of intense rainfall, severe cyclones along the coastline and an increase in flooding. Rising sea levels along the coast are likely to compound these problems by aggravating saltwater intrusion and soil salinity in the coastal areas and river deltas. Risk reduction will require

household as well as system-level investments in diversification and water control to manage increasingly unpredictable swings in seasonal rains and drought.

Due to budget constraints, most flood protection structures are only being maintained at a minimal level at present, increasing the risk of floods. Over the next 20 or 30 years it is essential that flood defences are improved − raising the height of embankments and strengthening them, replacing or repairing sluice gates, renovating or constructing drains and protecting riverbanks.

3.2. Soil and water conservation

Soil and water conservation, though not a priority from village consultations, is important in three contexts: reducing and repairing land degradation; protecting infrastructure from sediment damage; and managing water effectively in rainfed systems at both field and watershed scales. The emphasis should be on working across catchments to slow the movement of water through the landscape, to enhance infiltration and availability of water and reduce erosion. Low cost water conservation practices in rainfed uplands are important to improve crop yields and to reduce production risks and droughts.

4. INSTITUTIONAL ENVIRONMENT

4.1. Government institutions

The MoAI is responsible for all aspects of agriculture and irrigation. Under the MoAI the ID is responsible for all gravity irrigation systems, flood control infrastructure and drainage, while the WRUD undertakes all pumped irrigation schemes, whether from rivers or from groundwater. The Agricultural Planning Department has responsibility for planning, monitoring and evaluation of all agricultural projects, including both gravity and pumped irrigation schemes and flood protection works. Supporting institutions important to irrigation include the Irrigation Technology Centre in Bago and the Agricultural University of Yezin.

In addition to the ID and WRUD, a number of other agencies have responsibility for protection and management of water resources. Under the Ministry of Transport: (1) The Directorate of Water Resources and Improvement of River Systems has responsibility for (i) improving and protecting waterways and river systems particularly for navigation; and (ii) monitoring water quality and quantity, and preventing river water pollution. (2) The Department of Meteorology and Hydrology is responsible for (i) weather/water monitoring stations, sediment discharge stations on main rivers and big tributaries, (ii) water quality stations on the Ayeyarwaddy Delta for measuring discharge and sediment flows and monitoring salt intrusion. Municipalities and township development committees are gradually taking responsibility for urban water supplies. The Ministry of Environmental Conservation and Forestry (MOECF) is responsible for watershed management and reducing sedimentation in lakes, reservoirs, rivers and other waterbodies.

Agencies important to soil and water conservation activities include the Extension Division and Land Use Division of the MoAI and the Environmental Conservation Department and the Dry Zone Greening Department of the MOECF.

Some research undertaken by the Department of Agricultural Research is of relevance to irrigation and to soil and water conservation.

Irrigation Department

The ID is charged with the provision of gravity irrigation systems, flood control infrastructure and drainage. It is headed by the director-general who is assisted by two deputy directors-general, one for Lower Myanmar and the other for Upper Myanmar. The department is organized into its head office and divisions for construction, maintenance and mechanical engineering. The head office comprises nine sections including geology, hydrology, survey and investigations, planning and works, design, procurement, and works inspections.

Nine construction divisions, headed by directors and deputy directors, are located in the vicinity of major construction sites. Each state or region has a maintenance division. Mechanical engineering divisions are located in Yangon, Taungoo, Magwe and Mandalay. Overall the ID employs over 13 000 staff, of whom 815 are officers.

The ID is charged with four main tasks: (1) carrying out investigations and surveys for irrigation, drainage and flood control projects; (2) planning and construction of new projects; (3) operation and maintenance (O&M) of existing irrigation, drainage and flood protection works; and (4) the provision of technical assistance to small-scale rural irrigation works and rural development.

Strengths of the ID include well-qualified engineering, geology, soils and hydrology staff and strong linkages with other MoAI departments and with local authorities.

Weaknesses include (i) lack of irrigation agronomy and participatory planning expertise for irrigation system design and management; (ii) lack of a farming systems and water management approach, (iii) shortage of funds for investment in irrigation facilities and service delivery, and flood protection works; and (iv) poor coordination with other ministries such as MOECF.

Water Resource Utilization Department

The WRUD is responsible for all pumped irrigation systems and rural water supply. The main functions of the WRUD include: (1) increasing agricultural production through the development of river pumping, and through the utilization of groundwater resources; (2) supplying rural areas with potable water from tubewells; (3) supplying irrigation and drinking water from spring sources by gravity flow systems in the mountainous regions of the border area and remote areas; and (4) introducing sprinklers and drip irrigation systems to farmers.

The WRUD is organized into three levels − the head office, state/region level and district level. It has six divisions with a total of 6 500 staff. The divisions include (1) Administration and Accounts, (2) Planning, (3) Water Pump, (4) Groundwater, (5) Gravity Flow and Civil Work and (6) Production and Procurement.

The WRUD manages the construction, O&M of major pump irrigation projects, with command areas of up to 40 000 acres using high discharge pumps. Currently several irrigation projects are being designated as special projects managed by respective special task forces in order to accelerate project implementation.

Strengths of the ID include well-qualified mechanical engineering, geology and hydrology staff and strong linkages with other MoAI departments and with local authorities.

The WRUD suffers from similar weaknesses to the ID, including (i) a lack of irrigation agronomy and participatory planning expertise for irrigation system design and management; (ii) lack of a farming systems and water management approach, (iii) shortage of funds for investment in irrigation facilities and service delivery; and (iv) poor coordination with other ministries such as the MOECF. In addition, the WRUD lacks civil engineering staff for designing the canal systems and structures to distribute pumped water.

Irrigation Technology Centre (ITC)

The ITC was established in Bago in 1988 with funding from the Government of Japan. The main aim of the centre is to upgrade irrigation technology and water management in Myanmar. Initially it concentrated on testing construction material, establishing improved design criteria, irrigation engineering, hydraulic modelling and the provision of training to graduate students and staff of the ID. Emphasis is now on water management of main and downstream irrigation facilities, on-farm water management, system development, development of an irrigation management information system and the provision of training. It is expected that the centre will make an important contribution to the development of improved operation and maintenance techniques. Emphasis is moving towards the organization of farmers into WUGs and increased participation of farmers in the operation, maintenance and management of the systems. However, most staff members have a background in hydraulic and civil engineering with little experience in either on-farm water management or in participatory methods. Funding of the ITC may become a constraint as it is

no longer heavily subsidized by the Government of Japan. The irrigation management information system is very sophisticated, comprising satellite imagery, georeferenced irrigation area information, computer-aided design, a land-use ledger system and a water management and monitoring system. The system has the potential to become an important tool in future irrigation performance assessment and monitoring, but is less suitable for daily water management support. The centre has excellent laboratory facilities, equipped by JICA, to test soils, water and construction materials.

Yezin Agricultural University (YAU)

The YAU is located within the dry zone of Myanmar, on good agricultural land with access to irrigation from the nearby Yezin dam. The university has nine departments covering agronomy, botany, agricultural chemistry (responsible for irrigation and water management), entomology, plant pathology, horticulture, agricultural economics, animal sciences and agricultural engineering. However, it suffers from a number of constraints including a limited budget, a curriculum biased towards theory rather than practice, outdated staff knowledge and skills, very low salaries and incentives, and lack of modern facilities and equipment. It has weak external linkages, in particular weak connections with other services supporting staff and farmers at field level, so information and knowledge developed at higher levels fails to reach the grassroots level. It is getting to grips with the need for greater interaction between engineers, soil scientists, agronomists, environmentalists and social scientists to ensure that new irrigation developments achieve their intended performance goals. It lacks expertise in the field of on-farm water management to improve water-use efficiency in irrigation systems.

Department of Agricultural Research

The Department of Agricultural Research (DAR) has seven crop research centres and 15 satellite farms representing different agro-ecological zones.

Topics under research that are relevant to water and soil management include techniques for flood and drought areas, salt-tolerant rice varieties, water-saving irrigation techniques for rice, short season varieties for dry areas, zero tillage for maize in Northern Shan State, hedgerow systems and conservation agriculture techniques in the Dry Zone. However, applying research findings to farmers' fields remains a problem. The DAR's links to the agricultural extension system, while good at the regional level, are very weak at township and village levels and with farmers.

The DAR has committed staff, but the more experienced are now retiring. Lack of investment has led to decline in the number and quality of research staff and of research facilities. Until recently, international sanctions hindered access to external knowledge and resources.

Land Use Division

The Land Use Division (LUD) under the Myanmar Agriculture Service (MAS) of the MoAI is responsible for soil surveys, soil maps and coordinating research activities with related agencies for soil conservation and land improvement practices. It also undertakes research into problem soils and their amelioration, and soil fertility investigations in farmers' fields. It has ten divisional offices in the country, each with 10-30 staff, who play an important part in land allocation. At the township level the LUD is involved in land consolidation projects. Also, LUD staff are closely involved in the implementation of centrally-planned cropping patterns. In Shan State the LUD has developed several small plots demonstrating soil

conservation techniques, such as sloping agricultural land technology and contour bunding, in cooperation with local farmers.

In collaboration with UNDP and the Settlement and Land Records Department (SLRD), the LUD has been involved in the development of a land classification project. The work involved extensive soil surveys and mapping and the LUD has developed some capacity in geographical information systems (GIS).

In common with other government agencies, the LUD suffers from a shortage of funds, low salaries and lack of well-qualified staff in water and land-use planning and management.

Ministry of Environmental Conservation and Forestry

In 2005, the Ministry of Forests absorbed the National Commission for Environmental Affairs (NCEA) which was the main environmental authority at the time and comprised 19 heads of departments from various sectoral ministries. In 2012 the MOECF was formed by combining the former Ministry of Forests with the NCEA, which became the Environmental Conservation Department. The MOEFC is responsible for climate change mitigation and biodiversity conservation. It is the coordinating body of the Myanmar National Adaptation Program of Action working for climate change mitigation. The MOECF was responsible for drafting the current Environmental Conservation Law which was passed by Parliament in 2012. The central goal of the law is to safeguard the nation's natural resources for the benefit of present and future generations. This reflects the growing importance placed by the government on environmental protection.

The mandate of the Environmental Conservation Department includes: (i) providing guidelines for environmental quality standards and pollution control; (ii) implementing the national environmental policy and the strategy and action plan for integrating environmental consideration into the national sustainable development process; (iii) managing natural resource conservation and sustainable utilization, pollution control of water, air and land; and (iv) cooperating with other government organizations, civil society organizations, the private sector and international organizations concerned with environmental management.

Also under the MOECF, the Dry Zone Greening Department was established in 1997 with the specific aim of conserving the environment and watersheds of 13 districts of the CDZ. In addition to forestry activities, it undertakes water resource development and soil conservation activities including construction of small ponds to supply water for trees, people and animals, sinking of tubewells to supply water for nurseries, plantations and community use, construction of check dams to reduce runoff and erosion, and construction of rainwater collection tanks in public places such as village schools.

Whilst forest resource management has a long history and is backed by a well-established Forest Department, the MOECF has insufficient technical expertise or funding to effectively carry out its environmental management mandate. Another weakness is lack of coordination with other ministries, particularly the MoAI. Poverty is a root cause of shifting cultivation, land degradation and deforestation and needs to be tackled jointly by the MOECF and MoAI.

Township councils and village tract committees

Township and village tract committees play an important role in the development and management of agricultural and government irrigation systems. The committees responsible for irrigation schemes are headed by the township or village tract chairpersons and members include representatives of the ID, LUD WRUD, MAS, AMD and, in some cases, farmer

representatives. The committees organize maintenance by WUGs and decide on cropping patterns, often with little participation of farmers who, in theory, are represented by the ID.

4.2. Donor organizations

At the end of 2013 it was decided to establish a Development Partners Group (DPG) with membership open to all of Myanmar's bilateral and multilateral development partners. The overall objective of the DPG is to improve development assistance effectiveness and coordination

A number of UN, multilateral and bilateral donors are involved in agricultural water and soil management activities in Myanmar. Most of these are members of the Sector Working Group (SWG) for Agriculture and Rural Development which was established in 2013. It is chaired by the Director-General of the MoAI, and includes ADB, Australia, EU, France (AFD), ILO, Israel, Japan/JICA, KOICA, Netherlands, New Zealand, Switzerland (SDC), UK (DFID), UNDP, UN-HABITAT, UNODC, UNOPS, the World Bank and WFP. A Water Resource Group led by the Netherlands and World Bank was established in 2014.

In the area of water resource planning and management, the Netherlands is funding an IWRM strategic study and the World Bank is supporting the AIRBM which is scheduled for approval in December 2014, with a budget of US$100 million.

The World Bank supported agriculture-related projects in Myanmar during the 1970s to 1990s, included provision of irrigation facilities. It has recently resumed activities in the country. In addition to AIRBM, it has one active and one pipeline project in the agriculture and rural development sector. A grant of US$80 million for the Myanmar National Community Driven Development Project was approved in November 2012. It will enable rural communities to benefit from improvements to small-scale infrastructure and services, including irrigation. The Agricultural Development Support Project is scheduled for approval in February 2015. It is expected to cost US$100 million over five years and has the objective of increasing crop yields and cropping intensity in targeted irrigated areas Nay Pyi Taw, Bago-East, Mandalay and Sagaing regions. Beneficiaries are expected to include farm households with direct access to irrigated land, households which engage as workers on the irrigated land and households that participate in labour-intensive works of rehabilitation and maintenance of irrigation infrastructure.

The Asian Development Bank (ADB) restarted its development assistance to Myanmar in 2012, after an absence of 25 years. In December 2013 it approved a grant of US$12 million for the project Enhancing Rural Livelihoods and Incomes, which covers the Ayeryawaddy Delta, the CDZ, Taninthayi region and Shan State Plateau. It is envisaged that irrigation and drainage systems will be amongst the small-scale infrastructure interventions prioritized by communities for support under the project. In 2014 ADB started preparation of the Command Area Development Project which will have a budget of US$75.0 million. This project will improve the performance of irrigated agriculture to ensure increased agricultural productivity and farmer incomes in the CDZ. In the ADB pipeline is the proposed Flood and Drainage Management Project in the Delta, scheduled to start in 2016.

The Japan International Cooperation Agency (JICA) has been active in irrigation. It supported the South Nawin Irrigation Project in the late 1980s/early 1990s. In 1988 it helped to establish the Irrigation Technology Centre in Bago and provided support until 2004. This included establishing some 300 acres of model plots demonstrating appropriate water

management technology in Ngamoeyeik Irrigation Scheme in Hlegu. In September 2014 JICA signed an Overseas Development Assistance (ODA) loan agreement providing US$137 million for funding the Irrigation Development Project in Western Bago Region. The project is due to be completed in 2018. Irrigation efficiency will be improved by upgrading irrigation infrastructure, providing equipment and introducing crops and cropping patterns needing less water. The project will contribute to an increase in agricultural production and an improvement in the livelihoods of farmers in the region.

IFAD approved its first loan to Myanmar in April 2014, providing US$19.5 million for a project designed to introduce best practices in sustainable, scalable smallholder agricultural and rural development across the Central Dry Zone. The project has two components. The agricultural infrastructure development component will contribute to the ongoing expansion of irrigated areas and to smallholder farmers' empowerment, particularly in relation to the O&M of irrigation schemes. The second component, agricultural and business services, will help rural households to access services and technologies enabling them to improve their productive and economic activities.

The United Nations Development Programme (UNDP) supported the Human Development Initiative (HDI) from 1994 until 2012. A budget of US$56.1 million was used in the CDZ and border areas to tackle health care, education and food security. Three of the 10 HDI projects were implemented by FAO and related to food security. Agricultural assistance included construction or rehabilitation of 700 irrigation canals, construction of 24 dams and development of sprinkler irrigation on 1 500 ha. UNDP is now funding the Environment, Climate Change, Energy and Disaster Risk Reduction Programme which covers the delta and coastal regions, the CDZ and the northern forests. It has an indicative budget of US$46.6 million. The programme will focus on strengthening national capacities to manage and use natural resources in a sustainable way, while increasing resilience to short- and long-term climate variability and the associated risk of natural disasters. Project activities will focus both on policy and capacity development at the national and community levels in disaster-prone zones and areas of environmental degradation in Myanmar.

The United Nations Environment Programme (UNEP) and **FAO** are important sources of information on soil and water conservation and have been active in soil and water conservation programmes in the CDZ in recent years. **ICIMOD** has recently started funding soil conservation activities in Shan State aimed at protecting Inle Lake, mainly in the form of demonstration plots.

4.3. Non-government organizations

The INGO Forum, established in Myanmar in 2007, now has 69 members drawn from international nonprofit making agencies that undertake humanitarian, recovery and development work. The Myanmar NGO Network for local NGOs was formed in 2009 and has over 100 members, a number of whom undertake agricultural and environmental activities.

NGOs such as Proximity Designs (formerly IDE) and Cesvi have experimented with small-scale irrigation and drip systems. They have also supported rehabilitation of village ponds in the CDZ. Proximity Designs produces treadle pumps, small-scale drip irrigation systems and low-cost water storage tanks.

The International Volunteers Service Association (AVSI) aims to improve food security through sustainable agriculture. This includes quality seed multiplication, promotion of low-input and organic-based technologies, increase of irrigation water, provision of farm machinery and equipment, rehabilitation and construction of tubewells, soil conservation and capacity building.

The Water, Research and Training Centre is a nonprofit educational foundation promoting and improving access to research, training opportunities and education in the water and rural sectors. It has recently launched a new initiative in Myanmar − Programmatic Approach to Agricultural Water Management. This initiative will be addressing: (i) water-use efficiency and productivity; and (ii) best practices for water use and conservation.

CARE is interested in food and livelihood security through improvements to agriculture, investment in irrigation systems, and fisheries and livestock development.

Terre des Hommes Italia (TDH Italia) supports livelihood and agricultural development through construction and rehabilitation of wells, boreholes, water systems and networks, ponds and dams for domestic and agricultural use, and hydroponic water-saving farming methods.

4.4. Civil society organizations

Until recently civil society organizations (CSOs) in Myanmar have received little encouragement and have played little part in the development of the country. Informal family- and community-based networks are strong, but the capacity of CSOs such as farmers' organizations, irrigation water user groups (WUG) and agricultural cooperatives is limited.

Most large irrigation schemes have WUGs, each with 10 to 20 members, and based on lower level hydraulic units. The WUGs are responsible for repair and maintenance of the field channels and tertiary canals and ensuring the fair distribution of water. They are subordinate to the Township Agriculture Supervision Committee or a Village Tract Committee. The committees are headed by the township or village tract chairperson and members include representatives of the ID, LUD, WRUD, MAS, AMD and, in a few cases, farmer representatives. All decisions are made in a top-down manner. Farmers, for example, are told what crops to grow each season, when water will be available to them, and are instructed to carry out maintenance work. The result is that farmers often leave their land fallow rather than grow an unprofitable second crop of rice and maintenance is neglected.

WUGs are typical of CSOs in that they are weak and have no legal basis. There is no policy, strategic or institutional framework that sets out the rights and obligations of irrigation stakeholders and WUGs. A key constraint is the lack of an enabling environment, which normally requires: (i) a stakeholder dialogue and consensus-building process; (ii) an enabling legal framework in which the legal status, membership, rights and responsibilities of members are clearly stipulated; and (iii) a capacity-building and support programme.

It is increasingly realized that successful irrigation management in Myanmar cannot be accomplished without the active participation of water users and farmers. In some case the ID is seeking more farmer participation by forming Canal, Weir or Dam Committees, headed by an experienced farmer and assisted by ID staff, to take charge of operation and maintenance.

4.5. Private sector

The government is now encouraging the private sector to undertake agricultural enterprises in Myanmar. This includes some irrigation development. For example, the Chinese lease land in northern Myanmar for extended periods to grow irrigated water melons. Also, a Thai company, Big M, started a small irrigated fruit and vegetable farm near Taunggi in Shan State eight years ago and is now developing a similar, but much larger, farm near Nay Pyi Taw. Some local farmers are now copying techniques that they have seen on these schemes.

Many private farmers have invested in portable diesel pumps to irrigate from rivers, canals or groundwater and, now that landownership is becoming more secure, some are starting to invest more in their land by, for example, installing sprinkler irrigation systems.

5. KEY OPPORTUNITIES AND CONSTRAINTS TO SECTOR DEVELOPMENT

5.1. Water resources, irrigation and flood control

Constraints

Myanmar has abundant surface water resources, but roughly 80 percent of freshwater flows during the May to October monsoon season and only 20 percent during the dry season. Groundwater is being widely promoted as a solution to water resource issues, particularly in the Dry Zone, but inadequate data on aquifers mean that there is a high risk of unsustainable development.

Economic development will intensify urbanization and industrialization and increase competition for water resources particularly in the dry season and, in the absence of environmental legislation, is likely to lead to pollution of rivers, groundwater and other waterbodies. Water rights will become increasingly important as successful borehole or river extraction development occurs.

At present, inadequate water sector statistics and data are a serious constraint to water resource planning and coordination among water users and the different agencies dealing with water resource development.

A comprehensive analysis of the water sector, both surface and groundwater, and the development of a coherent development strategy to guide water resource investment in the future are urgently required to avoid piecemeal development with limited impact and high risk of unsustainable practices. An effective nationwide water-related data management system is needed, which comprises an extensive monitoring networks supported by appropriate data collection protocol and modern easily accessible databases and analysis tools.

The ID and WRUD account for well over 50 percent of the total MoAI annual budget but irrigation covers less than 20 percent of arable land in Myanmar, a good deal less than in neighbouring countries such as Thailand (27 percent), Viet Nam (32 percent), India (34 percent) and China (47 percent).

Whilst the ID is relatively strong on the infrastructure development side of irrigation and flood control, and the WRUD has well-trained mechanical engineers, geologists and soil specialists, neither department has skills in irrigation agronomy, irrigation water management, participatory management and development, or environmental protection. In addition, the WRUD is understaffed and has no civil engineers to develop the irrigation canal systems to distribute pumped water. Both departments suffer from budget constraints that effect both the standard of initial infrastructure constructions and the O&M of schemes.

The performance of formal irrigation schemes has been suboptimal, with actual areas irrigated much lower than nominal command areas. A government report released by the Auditor General's Office in 2012, found that "Sixty-seven river water pumping stations have achieved 16.3% of their target, providing water to 48,833 acres out of the 299,895 acres originally planned", and that some reservoirs and diversion dams could not supply water at all. This is attributed to a wide range of issues including system design, O&M issues, availability of power for pumping, and inappropriate siting and soils. Many systems were designed to grow rice under flood conditions and are insufficiently flexible for other crops; there is a lack of extension of agronomic advice to assist farmers to make best use of

irrigation. These issues are compounded by inadequate funding and technical capacity for operation and maintenance.[7]

Particular issues with ID and WRUD irrigation schemes include:

a. Inadequate feasibility studies prior to design and construction mean that the actual irrigated area is often considerably lower than that designed. Also, little account is taken of topography, and soil types and their quality, in some cases leading to canals with high levels of seepage, inadequate drainage, waterlogging in depressions and raised areas out of command.

b. While many reservoirs and irrigation schemes have been built in recent years some have not been fully developed, due to shortfalls in the budget for construction of the canal network and structures. Provision of tertiary and farm-level channels are generally the responsibility of farmers and, where they exist, are poor quality. The result is inefficient water use, with a tendency for excess water extraction near canal headworks while farmers at the tail end receive insufficient water or none at all.

c. Lack of land levelling leaves high areas out of command and low areas waterlogged. Where land levelling has been carried out, due to lack of funds, no effort has been made to follow good practice by removing the topsoil, levelling the subsoil and then replacing the topsoil. This results in infertile subsoil being exposed on sections of the levelled area, leading to reduced crop yields despite irrigation being possible.

d. Management, O&M of schemes are often poor due to staff shortages, inadequate budgets and lack of farmers' participation in decision-making. Much of the infrastructure on some large irrigation schemes is in poor condition.

e. The productivity of land in irrigated areas is suboptimal because of the highly fragmented pattern of small bunded basins with irregular shape at slightly different levels. It is also inequitable as upstream users have a clear comparative advantage in terms of securing the required amounts of water and fine-tuning the cropping calendar with the availability of water in the canals. Practically, rice is the only crop that can be cultivated by the downstream users under these flow and drainage conditions, preventing possibilities to respond to market demands and making the farmers' incomes subject to externalities such as fluctuations in the rice price. Moreover, the high and continuous water requirement of summer rice makes rice growers highly vulnerable to any reduction of flow from dams. The plot-to-plot system also results in suboptimal use of agricultural inputs (pesticides and fertilizers) regardless of the level of inputs used.

f. The impact of waterlogging and salinization on farmers and local economies can be insidious. In the initial years, the introduction of irrigation often causes a dynamic transformation of local and household economies. Farmers introduce high-yielding varieties of grain and are able to grow valuable market crops.

[7]IWMI. 2013. *Identifying priority investments in water in Myanmar's dry zone: Final report for Component 3.*

Wealth is created. However, as the water table rises, the economy based on unsustainable water management practices deflates. Once salinized, land and the unsaturated zone of the soil are difficult and expensive to reclaim. Ultimately, many farm families (and regional economies) may be worse off than before the introduction of irrigation unless sustainable and affordable methods of remediation are found.

g. In some areas farmers are still obliged to grow just rice under irrigation, but the profit from irrigated rice is very low. With few incentives to grow paddy during the dry season when production costs are higher, many farmers grow no crop at all. Cropping intensity on existing schemes is sometimes less than 100 percent, and often less than 150 percent. Many farmers would like to grow more profitable crops, at least in the dry season. Farmers growing non-paddy rainfed crops often earn more than farmers with irrigation.

h. WUGs are weak and have no legal basis. There is no policy or institutional framework that sets out the rights and obligations of irrigation stakeholders. It is increasingly realized that successful irrigation management in Myanmar cannot be accomplished without the active participation of water users and farmers.

i. Shortage of farm labour is becoming a problem, particularly near cities, larger towns and in tourist areas. The layout of irrigation schemes and lack of farm roads often makes mechanization difficult.

j. Diesel engines provide the power for over 90 percent of the irrigated land served by pumped water. Provision of electricity would reduce the pumping costs considerably.

k. Until recently the WRUD did no testing of soil or water quality when developing groundwater irrigation and in some areas this has led to severe salinity and sodicity problems.

l. A water tax paid by farmers on government schemes is based on the area farmed and farmers have no incentive to be economical with water. In some areas, farmers consider water taxes to be voluntary as there is no penalty if they do not pay. Excess water may carry fertilizer and pesticides into watercourses. Irrigation service fees for gravity-fed systems are very low (900 kyat/acre for monsoon paddy, 1 950 kyat/acre for dry season paddy and 900 kyat/acre for non-paddy crops) and do not cover recurrent costs, so much of the management and maintenance costs are met from the limited budget of the ID. Higher fees apply in pumping systems operated by the WRUD (6 000 kyat/acre for monsoon paddy, 9 000 kyat/acre for summer paddy and 3 000 kyat/acre for non-paddy crops). The higher fees, however, discourage farmers from dry season cultivation of paddy. In principle, O&M costs should be covered by the water fees but, for example, on pumped schemes using electricity it is estimated that the water fee covers only 23 percent of the electricity costs.

m. Availability of agricultural extension is limited and few, if any, extension officers have training in irrigation agronomy and on-farm water management. Farmers tend to ignore the irrigation demonstration plots established in many

areas as the irrigation infrastructure at the farm level does not enable good control of water and they do not have access to, or cannot afford, good quality seed, fertilizer, pesticides and other inputs.

n. Accelerated soil erosion caused by upland deforestation and poor farming practices is causing siltation of reservoirs, ponds and canals. Consequently, the economic lives of reservoirs are shortened, and the storage and conveyance capacity of reservoirs, ponds and canals is reduced.

o. No monitoring and evaluation system exists for completed irrigation projects.

Due to climate change, there is a likelihood of more frequent intense rainfall and severe cyclones along the coastline, and an increase in flooding. Rising sea levels are likely to compound these problems by aggravating saltwater intrusion and soil salinity in the coastal areas and river deltas. Improved flood control measures are vital, particularly in the Delta Region. Budget constraints mean that most flood defences are only being maintained to a minimal level at present, increasing the risk of failure and floods. Over the next 20 or 30 years it is essential that flood defences are improved − raising the height of embankments and strengthening them, replacing or repairing sluice gates, renovating or constructing drains, and protecting riverbanks.

Opportunities

To reduce the potential for conflict and achieve the greatest economic and social benefits, a legal and policy framework is needed to promote sustainable water resource planning and management in a river basin context. It appears that this will be comprehensively covered through the Netherlands-funded IWRM and the World Bank's AIRBM projects. The exact scope and scale of these projects needs further investigation.

Although growth in food crop production appears to be levelling off, there is scope for expansion of the subsector. Current rice yields of about 4.1 tonnes/ha could be raised to at least 5.0 tonnes/ha with increased irrigation and adequate inputs. Further, with improved and expanded irrigation in the dry season, the annual cultivated area could be increased.

Many schemes involve both gravity water distribution systems and pumping. Consideration should be given to improving the efficiency of irrigation and flood control intervention delivery through amalgamating the ID and WRUD into one department (perhaps renamed the Irrigation and Flood Control Department). Capacity building of staff and extending the range of skills through the recruitment of staff with expertise in irrigation agronomy, irrigation water management (including water-use efficiency), participatory irrigation management and development, and environmental protection and management, would improve their abilities for efficient irrigation service delivery.

Opportunities for improving water resource management and irrigation systems include:

a. Rehabilitation and upgrading of existing irrigation facilities, particularly in the CDZ, could lead to much more efficient water use, enabling larger areas to be irrigated at relatively low cost.

b. There is some potential for new large-scale gravity irrigation systems, particularly where a dam has already been constructed for hydroelectricity, for example.

c. Groundwater resources appear to be relatively abundant and largely untapped. However, before extensive development is carried out, it is essential to complete and update past groundwater surveys. Comprehensive data on the locations, depths, extent, replenishment rates and water quality of suitable aquifers are needed. Also, to reduce the danger of overexploitation of groundwater, a countrywide database should be established of groundwater wells, including their location and regularly monitored groundwater levels and water quality. This can build on data held in local WRUD offices, but should also include a structured survey of well-drilling companies and individuals to capture local knowledge of the location, extent and reliability of groundwater resources. Further work is needed to determine the extent and prevalence of arsenic in groundwater which is a particular hazard in the Ayeyarwaddy Delta but has also been identified in a few locations in the CDZ.

d. Small schemes for groups of farmers taking water from ponds, from weirs on small hill streams or pumping from shallow tubewells in areas with good quality aquifers, offer opportunities for irrigation of vegetables and oil crops such as sesame and sunflower. These could be assisted under stand-alone projects or as a component of community development projects.

e. Provision for good drainage, land levelling (preserving the fertile topsoil) and farm roads should be incorporated into all rehabilitation and new irrigation works.

f. Stakeholders should be consulted throughout the process of rehabilitating or developing new irrigation systems to ensure that the works meet their needs. Capacity building of scheme staff, local agricultural extension officers and farmers should be an important element, particular attention being given to participatory O&M, irrigation agronomy and on-farm water management. Efforts should be made to ensure that women are included in consultations and activities, including training. The long-term aim should be transfer of management of all but the largest schemes to farmers through incorporating the WUGs into well-organized water-user associations with established rules and regulations, defined rights and obligations of stakeholders, and well-trained committees. Training required would include topics such as organizing meetings, planning water distribution, planning maintenance, financial budgeting and dealing with disputes.

g. To reduce water wastage in irrigation schemes, all new and rehabilitation works should incorporate water-measuring devices throughout the system. Water charges based on actual usage, perhaps at the WUG level, should gradually be introduced.

h. At present, flood control structures provide protection from all but the worst storms, such as Cyclone Nargis in 2008. However, climate change is likely to cause more frequent intense rainfall and severe cyclones. There is still time to reduce the potential for catastrophic floods in the future, by improving flood protection infrastructure. Embankments, sluice gates, drains and other flood control measures need to be surveyed to determine rehabilitation and improvements required, both in the short and long terms. Proposals should be

prepared for phased implementation of the required works over the next 20 to 30 years.

Table 1: Summary of water resources, irrigation and flood control constraints, threats and opportunities

Constraints	Threats	Opportunities
• Absence of overall policies, legislation, and institutional structure for water resource management • Limited awareness among policy-makers and planners of the potential economic, social and ecological damage that can result from unregulated water resource exploitation • Limited basic data on rainfall, seasonal flows, fluctuations, current, river morphology and likely future levels of exploitation (including water extraction, water retention for hydropower, sand mining and industrial and urban development) • Limited information on groundwater aquifers, including recharge rates and water quality • Unclear institutional structure for the management of irrigation, drainage and flood control systems, especially at the beneficiary user level • Inadequate funding for sustainable management, O&M of water resources infrastructure. • Water pricing in government schemes is based on irrigated area rather than volume of water used and leads to excessive water use	• Unregulated retention of water for hydroelectricity generation, with little consideration of other uses, will reduce low season river flows, disrupt annual river flow patterns, intensify sea intrusion in delta areas, affect river morphology, and disrupt aquatic habitats • Increased competition for sparse low season flows among users, especially in the CDZ • Pollution from mining, industrial waste and sewage discharge near urban areas • Damage to standing crops, livestock, housing and rural infrastructure due to floods, restricted drainage and salinity intrusion. Climate change is likely to exacerbate the threat • Siltation from upland agriculture and forestry activities	• There is still scope for extending irrigation using surface water sources • Groundwater resources are relatively abundant and largely untapped • Some hydroelectric dams could support irrigation as well as power generation • Rehabilitating and improving existing irrigation schemes could lead to much more efficient water use, enabling larger areas to be irrigated at little incremental cost • Land resources in the Delta Region are vital to agricultural production. Rehabilitation and improvements to existing flood protection infrastructure will protect the land from severe storms, which are likely to become more frequent as a result of climate change. Initially flood protection works need to be inspected to determine the work required in the short and long terms

5.2. Soil and water conservation

Constraints

Deforestation, poor agricultural practices, overgrazing and shifting cultivation, all of which are exacerbated by the increasing population, are causing land degradation particularly in the upland areas. Although, farmers often recognize that erosion caused by wind or water is occurring on their land they do not know what to do about it. Control of land degradation and soil erosion in agricultural areas is not a high priority in communities or with the higher levels of government.

Government capacity to implement soil and water conservation measures and to reclaim degraded agricultural land is limited by insufficient expertise and funding. The main agencies responsible, the Environmental Conservation Department and the Dry Zone Greening Department of the MOECF and MoAI's Land Use Division use their limited budgets for demonstration plots. Physical conservation measures tend to be demonstrated, but most farmers are not interested in adopting the techniques because of the high labour requirements. Some donor-funded projects have also emphasized physical works such as terracing and contour bunds, often constructed by communities under cash-for-work schemes. Although donors appreciate the need for a catchment-wide approach to controlling soil erosion, in practice resources have been spread too thinly and the tendency has been to work with just the poorer villages, excluding better-off villages in the same catchment.

Physical conservation techniques may be effective in controlling runoff and erosion but are labour-intensive and often do little to increase production or incomes.

Opportunities

For conservation measures to succeed they must be seen by farmers as a means of attaining increased production in a sustainable way, not just as a means of controlling erosion. Low cost soil and water conservation practices in rainfed uplands can improve crop yields and reduce production risks and droughts. The emphasis should be on working across catchments to slow the movement of water through the landscape, to enhance infiltration and availability of water, and reduce erosion.

Biological conservation and moisture retention techniques, which make the best use of water where it falls, increase vegetative cover and generally improve soil structure and water-holding capacity. These may include:

a. Contour planting, strip cropping, relay cropping;

b. Putting degraded sloping cropland under permanent cover of fodder grasses and legumes;

c. Conservation Agriculture (CA) techniques which are characterized by: (i) minimum mechanical soil disturbance, (ii) maintaining a permanent organic soil cover and (iii) diversified crop rotations and associations. As people in the project areas are not familiar with some of these techniques, considerable effort would need to be put into training of both farmers and extension staff. On-farm tests and demonstrations would be a key component. Incentives in the form of implements such as jab planters and ox-drawn rippers or direct planters could be provided to groups of interested farmers to assist planting through crop

residues. (see *Review of crop production, extension and applied research in Myanmar* for further details.)

In drier areas such as the CDZ, however, where it is more difficult to implement vegetative methods, physical methods may be needed to help plants to become established and cover the ground quickly. Cash-for-work programmes may be needed

A regulatory approach to conservation is generally ineffective − farmers are more likely to respond to incentives and technical assistance. Incentives provided by aid agencies have often been counterproductive with a slow pace of work, follow-up maintenance neglected and, in some cases, conservation works constructed but then not used. Nevertheless, careful use of incentives is essential to encourage villagers to participate in conservation activities. These should be kept to a minimum and only used for works benefiting the community as a whole such as the planting of trees, for community groups testing new techniques and for conservation measures on public land. They should be in the form of the provision of materials and tools, funding of transport or equipment hire, and payment for a portion of the labour involved. Where cash-for-work is used, every effort should be made to employ the poorest members of a community.

6. POVERTY AND SOCIAL INCLUSIVENESS

Despite extensive fertile soils, ample water and a climate that is generally favourable to agriculture, there is a strong association between agriculture and poverty in Myanmar. The incidence of poverty in rural areas (29 percent) is significantly higher than in urban areas (15 percent). The rural poor typically comprise the landless who make up 35 to 53 percent of the rural population depending on the area, farmers with small and marginal landholdings (< 2 ha) and ethnic groups. The rural poor suffer from inadequate food, poor nutrition and lack of essential no-food items. Most of the poor live either in the CDZ where soils are sandy, rainfall low and population density high, or in the hill tracts populated by ethnic groups, which are remote, have limited arable lands and have been affected by conflict. The overarching goal of interventions in rural areas should be reducing poverty among poor rural women and men, particularly smallholders, the landless, ethnic groups and other marginalized groups.

Rural women are among Myanmar's most marginalized groups, with high vulnerability to food insecurity and poverty. Women also tend to be affected more severely by natural disasters and extreme weather events. Cyclone Nargis, for example, which killed about 140 000 people, resulted in twice as many deaths among women as men. Women tend to have fewer assets than men and depend more on natural resources for their livelihoods, making them more vulnerable to the effects of climate change, but their exclusion from decision-making limits their ability to adapt and mitigate the effects. While Buddhist customary law and the 2008 Constitution provide equal rights to women, they are not well represented in the political and higher-level administrative sphere outside of the traditional areas of social services, health and education. At the local level, there are few women representatives in decision-making bodies.

Women and men engage in most farm work together. Generally, men do the land preparation, ploughing and fencing, while women do the weeding and marketing. Men and women jointly plant, transplant, weed, harvest, thresh and perform postharvest tasks. They also jointly care for cows and buffalo, while small livestock (goats, pigs) and poultry are mostly tended by women. Women are in charge of domestic tasks such as gathering fuelwood, fetching drinking water, preparing meals and caring for children. In some areas near forests, women are also reported to be collecting mushrooms, nuts, and wild fruits and vegetables.

Floods, droughts and other natural disaster frequently lead to food shortages that disproportionately affected the poor and vulnerable. It is essential that flood protection works, particularly in the Ayeyarwaddy Delta, are upgraded and well maintained. The improvement and extension of irrigation systems will protect more farming households from the effects of drought and water scarcity that lead to food shortages and poverty, particularly in the CDZ. Well-designed and managed irrigation systems extend the growing season, increase farmer incomes and provide work for the landless.

Well-conceived and implemented measures to reduce runoff, soil erosion and land degradation in rainfed cropland and surrounding rangeland can protect infrastructure such as reservoirs from sedimentation and enhance the productivity of the land and resilience to climate change. This will improve the livelihoods of people in some of the poorest areas of Myanmar.

The participation of rural communities in the planning, implementation and subsequent management, O&M of irrigation works, flood control works and soil and water conservation activities is essential to their long-term sustainability. Women play a major part in crop production and every effort should be made to ensure that women, particularly those from female-headed households, have equal access to opportunities offered by interventions. Women and other disadvantaged groups, such as the poor and people with disabilities, should be actively encouraged to join farmer groups, WUGs, local agricultural and irrigation committees, etc., and participate in meetings and activities.

Implementation of irrigation and water control works presents opportunities for paid work. Also, cash-for-work is used by agencies for some activities, particularly soil and water conservation works and the construction or rehabilitation of ponds. Preference should be given to poorer and vulnerable people when paid work is available as this can provide a significant injection of cash into the poorest households. A significant proportion of participants should be women (possibly introducing a minimum quota of 40-50 percent), as they are responsible for household food expenditure. It is impo9rtant to emphasize an equal pay policy (although traditionally men are paid more than women) and to be aware of seasonal labour priorities and rates to avoid interference with the labour market. Special consideration should be given to the needs of those who are physically weaker among the community members with regard to: recruitment of workers, work systems, flexibility in working hours, provision of special facilities for female workers such as sanitary facilities and child care. Work schedules would be set by the communities, but should be flexible enough to allow labourers to participate without compromising on harvest work or daily housework. Guidelines for labour practices and checklists for regular monitoring of working conditions should be used throughout implementation. Labour practices should include a zero-tolerance policy on harassment.

7. RECOMMENDED AREAS OF INTERVENTION AND INVESTMENT

A range of interventions and investments has been identified to overcome constraints and make the most of opportunities in the agricultural water and soil management sector. Some, such as irrigation works, will have a direct impact by improving the livelihoods and food security of rural communities and reducing poverty. Other proposed interventions to improve the enabling environment will benefit rural communities in the long term through better government-provided services and ensuring resources such as groundwater are developed sustainably.

To reduce the potential for conflict and achieve the greatest economic and social benefits from development of water resources, a comprehensive analysis of the water sector, both surface and groundwater, and the development of a coherent development strategy to guide water resource investment in the future are urgently required. It appears that important interventions required to develop a Water Resources Master Plan, based on the concept of IWRM, will be comprehensively covered by the forthcoming IWRM strategic study funded by the Netherlands and the World Bank-supported AIRBM.

A necessary precursor to any large-scale development of groundwater is an appraisal of groundwater resources including recharge, sustainable yield of aquifers and water quality. A hydrogeological study of groundwater resources is a high priority of the WRUD and is proposed as an activity under AIRBM. The scope and scale of the AIRBM groundwater study should be checked to ensure it covers the full range of information needed for sustainable development of groundwater irrigation.

Under NAPA, recommended interventions and activities in the agricultural water and soil management sector include:

a. Monitoring of groundwater resources;

b. Improving the capacity of the MoAI for irrigation and flood protection service delivery;

c. Rehabilitation and modernization of existing ID and WRUD irrigation systems;

d. Development of small-scale community-managed irrigation schemes;

e. Upgrading of flood control structures in the Ayeyarwaddy Delta;

f. Participative, community-based soil and water conservation activities.

7.1. Monitoring of groundwater resources

Groundwater resources in Myanmar appear to be relatively abundant and have ample scope for development. Groundwater is of particular importance in the CDZ where many people depend upon it for domestic water supplies and for irrigation. Sagaing region has 21 000 ha, Mandalay 7 000 ha and Magway nearly 4 000 ha irrigated from shallow and deep tubewells. However, a study of the CDZ by IWMI[8]in 2013 found groundwater to be a more moderate resource than estimated in some earlier surveys, with about 4.7 km^3/year available. The

[8] IWMI. 2013. *Water resource assessment of the dry zone of Myanmar.* Final report. Livelihoods and Food Security Trust Fund /UNOPS.

IWMI report states that, whilst extremely important for the CDZ, groundwater must be planned and developed carefully to ensure availability in the long term.

Groundwater systems are dynamic and adjust continually to short- and long-term changes in climate, groundwater withdrawal and land use. Resources need to be carefully protected to ensure that withdrawal rates do not exceed recharge rates. Reductions in groundwater storage can have major implications for water quality because the salinity of the groundwater frequently increases as the volume of the aquifer decreases. Once modified or contaminated, groundwater can be very costly and difficult to restore.

Information is needed on the hydrological stresses acting on aquifers and how these stresses affect groundwater recharge, storage, discharge and quality. Long-term systematic measurements of water levels and water quality are essential to evaluate changes in the resource over time, to develop groundwater models and forecast trends, and to design, implement and monitor groundwater management and protection programmes. In addition, the models can play a central role where conflicts over groundwater resources or their management emerge.

Design of a monitoring programme is a complex exercise that requires knowledge and experience. The World Bank AIRBM groundwater study should provide a range of information helpful to the initial design of the monitoring system. Nevertheless, designing a monitoring programme is an iterative process in which the final product will result from considering and weighing different options. As experience with groundwater monitoring is limited in Myanmar, the monitoring programme should start in a relatively small area and then be gradually extended as experience is gained. A gradual approach will provide insight into the labour and costs involved in the final realization of the monitoring programme.

The objectives of groundwater monitoring are: (i) collecting, processing and analysing the data as a baseline for assessment of the current state, anticipating changes and forecasting trends in groundwater quantity and quality due to natural processes and human impacts in time and space; and (ii) providing information for improvements in the planning, policy and management of groundwater resources.

The following conditions are considered essential for successful monitoring:

a. A legal, regulatory, institutional and technical framework that allows for sustainable management and protection of groundwater resources.

b. Since irrigation is likely to be the major user of groundwater, responsibility for groundwater monitoring should lie with the WRUD. Some groundwater monitoring tasks may be delegated, but final responsibility should lie with the WRUD.

c. The capacity of the WRUD must be adequate to fulfil the task. Sufficient and suitable trained personnel, technical infrastructure, logistics and funding have been made available.

d. Monitoring must be coordinated with all other institutions working in the field of water resource management.

Data exchange structures are needed to optimize the benefits for all parties involved. The results and conclusions drawn from groundwater monitoring should made public at regular intervals.

7.2. Improving the capacity of the MoAI for irrigation and flood protection service delivery

The MoAI covers all aspects of agriculture and irrigation. Under the MoAI, the ID is responsible for all gravity irrigation systems, flood control infrastructure and drainage, while the WRUD undertakes all pumped irrigation schemes, whether from rivers or from groundwater.

Whilst the ID is relatively strong on the infrastructure development side of irrigation and flood control, and the WRUD has well-trained mechanical engineers, geologists and soil specialists, neither department has skills in irrigation agronomy, irrigation water management, participatory management and development, or environmental protection. In addition, the WRUD is understaffed and has no civil engineers to develop the irrigation canal systems to distribute pumped water. Both departments suffer from budget constraints that affect both the standard of initial infrastructure construction and the O&M of schemes.

Many schemes combine both gravity water distribution systems and pumping. Consideration should be given to improving the efficiency of irrigation and flood control intervention delivery through amalgamating the ID and WRUD into one department (perhaps renamed the Irrigation and Flood Control Department). The department's capacity for efficient irrigation service delivery would be improved through upgrading the skills of staff at central, regional and project levels in modern irrigation technologies, improved design, management, O&M of irrigation systems and extending the range of skills available through the recruitment of staff with expertise in irrigation agronomy, irrigation water management (including water-use efficiency), participatory irrigation management and development, and environmental protection.

Irrigation schemes that are being rehabilitated and upgraded can be used for practical training exercises.

7.3. Rehabilitation and modernization of existing ID and WRUD irrigation systems

In 2012/2013 the area under irrigation was about 2.1 million ha, with about 23 percent of the area double cropped. The government gives irrigation development a high priority in order to increase crop yields and cropping intensity. This is reflected in the large share of the development budget allocated to the construction and maintenance of irrigation schemes under current and proposed plans for the agriculture sector.

The urge to move forward with irrigation developments as quickly as possible has compromised the quality and sustainability of some projects implemented in the last 15 to 20 years. Many existing irrigation schemes function below their potential due to poorly developed systems and inadequate management, O&M. Reported problems with irrigation systems include inappropriate design that prevents adjustment of water supply according to variations in demand over seasons, incomplete tertiary canals and on-farm networks, unlined canals with high seepage rates, lack of land levelling, inappropriate crop choice and irrigation methods for the type of soil, and lack of maintenance and monitoring. Soil salinity and sodicity due to waterlogging, or the use of poor quality groundwater for irrigation, have reduced yields considerably in parts of a number of schemes, particularly in the CDZ. In some cases, land that produced reasonable yields under rainfed conditions has been abandoned, or produces very poor crops, as a result of the introduction of irrigation.

A focus on the rehabilitation and upgrading of existing irrigation schemes, as opposed to new construction, will allow rapid improvement of crop production under irrigation and extension of irrigated areas at relatively low cost because the basic structures already exist. Also, there will be few safeguard concerns as construction and development will take place mainly on existing sites. With improved management and a change in cropping patterns to nonrice crops it will be possible to expand the cropping areas and cropping intensity.

The CDZ should be a focus of support because:

a. It is the second most densely populated region of Myanmar after the Ayeyarwaddy Delta and has higher levels of poverty;

b. It is a traditional agricultural area and improved irrigation would significantly strengthen productivity and output;

c. The cost would be relatively low as the main structures have already been constructed; and

d. There is ample potential for improving and extending irrigation.

The selection of schemes for rehabilitation and extension should be based on: (i) their potential for increased crop production and poverty reduction, (ii) the condition of the existing system and the likely costs of improvements, (iii) possible environmental and social impacts – there should be no significant adverse environmental or social impacts, and no conflicts over land or water resources; and (iv) the implementation capacity of the MoAI, bearing in mind that organizations such as WB, ADB, JICA and IFAD are supporting major irrigation development. (IFAD and the World Bank are coordinating their respective investments, and the World Bank is considering using similar irrigation management and advisory services arrangements to those being set up under IFAD's Fostering Agricultural Revitalization in Myanmar Project.)

7.4. Development of small-scale community-managed irrigation schemes

The GOM has concentrated on developing large irrigation systems and limited attention has been given to providing support for small-scale community-run schemes, or to assisting individual farmers to develop irrigation. Small-scale irrigation[9] has been a component of some donor-funded livelihood-based and community development programmes. NGOs have assisted the development of a few small community schemes and have trialed the use of treadle pumps, sprinklers, drip irrigation and hydroponics. Due to their technical complexity and the high investment required, most farmers are still reluctant to try such technologies, but some private companies and better-off farmers use sprinklers. Some communities and many individual farmers have developed small areas of irrigation without outside assistance. It is estimated that private irrigation covers about 245 000 ha at present.

Small community schemes tend to provide supplementary water, particularly for rice, rather than full irrigation and drawn water from village ponds, diversion of flood flows, small weirs on streams or by pumping from surface water sources or groundwater. There is little information on the performance of these systems, but those seen during field visits were mainly producing food crops for home consumption, with a small surplus for marketing. Pumping technologies have become cheaper and more accessible in recent years and many

[9] Small-scale irrigation is often defined as schemes of 200 ha or less.

individual farmers are buying or renting pumps to draw water from shallow tubewells or surface sources. Sometimes within irrigation schemes tail-end farmers, or those with slightly higher land out of command, pump from groundwater or nearby canals. Small-scale, farmer-managed pumping has significant advantages in terms of flexibility, reliability and simple O&M. Where good quality groundwater supplies are available and sustainable, this has proved to be an affordable and effective way to increase production.

There is great potential for the development of more small schemes for groups of farmers taking water from surface sources or by pumping from shallow tubewells in areas with good quality aquifers, for irrigation of vegetables and oil crops such as sesame and sunflower. These could be assisted under stand-alone projects or as a component of community development projects. In addition, individual famers could be supported through technical advice and credit to develop pumped irrigation. At present, water-saving technologies such as sprinklers and drip irrigation are almost unknown and, sprinkler irrigation in particular, has the potential to play an important part in irrigated production (drip irrigation tends to be less popular with small farmers as it is expensive to install and, unless water is good quality, tends to suffer from frequent blockages).

Under NAPA a small-scale irrigation development programme is recommended. Under the programme, the development of both small-scale community-managed irrigation systems and irrigation by individual farmers, using both surface and groundwater resources, should be encouraged and supported. Farmers should be fully involved in all stages of development of irrigation systems and should bear the major part of the cost, with assistance provided to access credit. The role of the private sector in system development, equipment supply and support should be strengthened, especially for groundwater systems. This will require funding and technical assistance from a major aid agency for up to 10 years and involvement of NGOs.

7.5. Upgrading of flood control structures in the Ayeyarwaddy Delta

Much of the low-lying Delta Region is subject to flooding, storm surges and salinity intrusion, resulting in crop losses and reduced yields. In 2008, about 140 000 people died and as many as 2.4 million people were affected by Cyclone Nargis.

In the Ayeyarwaddy Delta, nearly 700 000 ha of good cropland is protected by over 2 000 km of embankments and drainage channels, including sea dykes in coastal areas to protect the land from saltwater intrusion. River embankments are also found in the upper Ayeyarwaddy River Basin, especially near Mandalay, where adverse land slopes leave land prone to flooding. Many of the structures in the delta were badly damaged by Cyclone Nargis which affected 50 townships, mainly in Yangon and Ayeyarwaddy regions. Rehabilitation is still ongoing leaving some of the most productive part of the country vulnerable to floods.

Flood control and drainage infrastructure will become increasingly important in the presence of global climate change. Weather patterns are increasingly difficult to predict, with drought one year and flooding the next. Most formal assessments suggest that climate change will affect Myanmar significantly. Major expected changes include rising temperatures, higher rainfall and a possibly a shorter rainy season, and an increase in severe cyclones along the coastline, which in combination will contribute to a considerable increase in flooding. Rising sea levels along the coast are likely to compound these problems by aggravating saltwater intrusion and soil salinity in the coastal areas and river deltas.

Myanmar needs to improve its ability to manage its increasingly unpredictable freshwater flows and minimize saltwater intrusion near the coast. Investments in improved water control infrastructure are fundamental to protecting agricultural land and the population in flood-prone areas, particularly in the fertile Ayeyarwaddy and Sittaung deltas.

Budget constraints mean that at present most flood protection structures are only being maintained to a minimal level, increasing the risk of flooding and saltwater intrusion. Over the next 20 or 30 years it is essential that they are improved − raising the height of embankments and strengthening them, replacing or repairing sluice gates, renovating or constructing drains and protecting riverbanks. The government would need to make commitments to increase the O&M budget for flood control infrastructure considerably to maintain the condition of existing structures and ensure the sustainability of rehabilitated and upgraded structures.

At present, flood control structures provide protection from all but the worst storms. There is still time to reduce the potential for catastrophic floods in the future, by improving flood protection infrastructure. Embankments, sluice gates, drains and other flood control measures need to be surveyed to determine rehabilitation and improvements required, both in the short and long terms. Proposals should be prepared for phased implementation of the required works over the next 20 to 30 years.

7.6. Participative, community-based soil and water conservation activities

Land degradation, particularly soil erosion in upland agricultural areas and dry zones, is an increasing problem in Myanmar. The main causes of land degradation include deforestation, poor agricultural practices, overgrazing and shifting cultivation, all of which are exacerbated by the increasing population, particularly in the upland areas.

About 10 percent of total cultivated land in the country is estimated to be vulnerable to severe soil erosion, with Shan State, Chin State and Sagaing Region amongst the most badly affected areas. Degraded farmland, as a percentage of total cultivated area, was estimated at 33 percent in 2008. The government capacity to implement soil and water conservation measures and to reclaim degraded land is limited by a lack of commitment at higher levels of government, and insufficient expertise and funding. Whilst donor-funded projects have emphasized the need for a catchment-wide conservation approach, in practice resources have been spread too thinly and the tendency has been to work with just the poorer villages, excluding better-off villages in the same catchment.

In Myanmar the emphasis is still on physical, rather than vegetative, techniques for control of runoff and erosion. Techniques such as terracing often do little to increase production or incomes and have a high labour requirements. The main emphasis should be on promoting biological conservation and moisture retention techniques which make the best use of rain where it falls, increase vegetative cover and generally improve soil structure and water-holding capacity (e.g. Conservation Agriculture). In drier areas such as the CDZ, however, where it is more difficult to implement vegetative methods, physical methods may be needed to help plants to become established and cover the ground quickly.

Due to inadequate budgets and staff, soil conservation activities on agricultural land undertaken by the LUD of the MoAI and MOECF, are mainly limited to small demonstration plots, sometimes carried out in cooperation with local farmers. Field days for farmers are held on these plots occasionally, but government officers complain that farmers are reluctant to

copy the techniques unless paid. This is particularly evident in the watershed surrounding Inle Lake in Shan State, an important tourist resource, where there is considerable concern about high siltation rates. The main emphasis of the MOECF has been on tree planting on the surrounding slopes. However, much of the watershed is agricultural land, including areas of shifting cultivation, and in these areas efforts to control soil erosion appear to be limited entirely to demonstration plots. ICIMOD has recently started funding soil conservation activities in this area, again mainly in the form of demonstration plots.

Although not a priority with communities, soil and water conservation is important for: (i) reducing and repairing land degradation; (ii) protection of infrastructure from erosion and sediment damage; and (iii) managing water effectively in rainfed systems at both field and watershed scales.

7.7. Indicative costs for components

The costs provided in Table 2 are very rough estimates at this stage.

Table 2: Project costs by subcomponents

Subcomponent	Total cost (US$)
1. Monitoring of groundwater resources	TBD
2. Improving the capacity of the MoAI for irrigation and flood protection service delivery	2 000 000
3. Rehabilitation and modernization of existing ID and WRUD irrigation systems	120 000 000
4. Development of small-scale community-managed irrigation schemes	3 000 000-4 000 000
5. Upgrading of flood control structures in the Ayeyarwaddy Delta	103 000 000
6. Participative, community-based soil and water conservation activities	TBD
Total component	TBD

TBD: To be decided

8. RELATION TO OTHER RURAL SECTORS

The agricultural water and soil management sector is closely linked to the crop, livestock, fisheries and forestry sectors.

8.1. Crop sector

Improvements to productive rural infrastructure alone are not sufficient to raise rural incomes and provide food security. Investments need to be complemented with the provision of services in order to maximize economic benefits and returns to the rural poor.

To take full advantage of a reliable water supply from new or rehabilitated irrigation systems, farmers also need improved agronomic and technology skills to increase productivity and allow the introduction of high-value crops. Through the agricultural extension system, they need advice on improved cropping patterns and farming systems under irrigation. In areas with saline soils they need assistance with amelioration techniques and access to seed of salt-tolerant crop varieties.

In areas prone to soil erosion and land degradation support is needed to improve soil and water conservation through agronomic and vegetative measures and introduction of techniques such as Conservation Agriculture.

8.2. Livestock sector

Measures to reduce soil erosion and rehabilitate degraded areas should include the planting of species suitable for animal feed, combined with controlled grazing; techniques such as cut and carry should be used. Consideration should be given to provision of water points for livestock near canals and other water sources so they do not damage infrastructure. Encouraging construction of community waterbodies in the form of ponds, tanks, etc. will also support development of the livestock sector which would in turn support agriculture through enhanced availability of organic manure.

8.3. Fisheries sector

Fish culture can be undertaken in reservoirs and in seasonal and perennial ponds, and may also be possible in larger canals. So far irrigation canal-based aquaculture has not been tapped at all. Runoff from irrigation schemes may pollute rivers with fertilizer and pesticides and affect fish populations. Runoff could be reduced through more efficient irrigation practices.

Conflicts have arisen between shrimp farmers and rice growers in the Ayeyarwaddy Delta regions, where shrimp farmers have sometimes breached sea dykes. Experiences of two pilot projects funded by the World Bank with the allocation of land to farmers have been discouraging, as conflicts over land use by rice and aquaculture prevail. A third project is now underway, covering two townships in the area. The LUD is involved in benchmarking activities.

8.4. Forestry sector

Agroforestry and community forestry are frequently among techniques employed to reduce runoff and soil erosion in order to protect watersheds above reservoirs and other important water resource infrastructure.

ANNEX 1: BIBLIOGRAPHY

Danish International Development Agency (Danida). 2013. *Myanmar farmers innovating for rural development and environmental restoration.* Denmark, Ministry of Foreign Affairs.

Economic and Social Commission for Asia and the Pacific (ESCAP). 1995. Assessment of water resources and water demand by user sectors in Myanmar.

ESCAP & LIFT. 2013. *An integrated rural economic and social development programme for livelihoods improvement in the dry zone of Myanmar.* United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and local partner Network Activities Group (NAG).

Food and Agriculture Organization of the United Nations (FAO). 2004. *Myanmar: agricultural sector review and investment strategy. Volume 1 – sector review.* TCI Main Report. Development. Investment Centre Division. Rome, FAO.

FAO. 2012. Country programming framework 2012 – 2016 for the cooperation and partnership between the Food and Agriculture Organization and the Republic of the Union of Myanmar. October 2012. Yangon, Myanmar.

FAO. 2013. *Report on Myanmar census of agriculture 2010.* The Republic of the Union of Myanmar, Ministry of Agriculture and Irrigation, Settlement and Land Records Department in Collaboration with FAO. Under TCP/MYA/3301(D). May 2013.

Groundwater Development Consultants (International) (GDC). 1984. *Burma umbrella project: groundwater exploration and pilot development sub-project.* Final report. 3 vols. Cambridge, UK. Unpublished report.

International Conference on Interdisciplinary Research and Development (ICIRD). 2012. *Farmer vulnerability amidst climate variability: a case study of dry zone of Myanmar.* By Khin Moe Kyi. ICIRD.

International Water Management Institute (IWMI). 2013. *Water resource assessment of the dry zone of Myanmar.* Final report. Livelihoods and Food Security Trust Fund /UNOPS.

Japan International Cooperation Agency (JICA). 2010. The development study on sustainable agricultural and rural development for poverty reduction programme in the central dry zone of the Union of Myanmar. Final report. August 2010. Prepared for Ministry of Agriculture and Irrigation, Ministry of Livestock, Fisheries and Rural Development, and Ministry of Cooperatives. Tokyo, Sanyu Consultants Inc.

Livelihoods and Food Security Programme (LIFT). 2010. *Framework for action for the central dry zone, Myanmar.* An initiative of the Food Security and Agriculture Thematic Group. Livelihoods and Food Security Trust Fund /UNOPS. July 2010.

LIFT. 2012a. Baseline survey results. Livelihoods and Food Security Programme (LIFT). July 2012. Yangon, Myanmar, UNOPS.

LIFT. 2012b. Increasing the efficiency and effectiveness of pumped irrigation schemes in the central dry zone of Myanmar. Working paper – 1: Irrigation and drainage systems. Formulation mission – July 2012. Livelihoods and Food Security Trust Fund /UNOPS.

LIFT. 2012c. Increasing the efficiency and effectiveness of pumped irrigation schemes in the central dry zone of Myanmar. Working paper – 3: Agriculture. Formulation mission – July 2012. Livelihoods and Food Security Trust Fund /UNOPS.

LIFT. 2013a. ADRA Myanmar and ActionAid Myanmar end of project evaluation of "Community Initiated Livelihoods and Poverty Reduction (CILPR) Project". Magwe Division, Myanmar. Livelihoods and Food Security Trust Fund /UNOPS. October 2013.

LIFT. 2013b. The geographical focus and conceivable activity options for the proposed LIFT dry zone programme. May 2013. Yangon, LIFT Fund Management Office, UNOPS.

LIFT. 2013c. Opportunities/constraints and options for consideration in a dry zone programme. Yangon, Myanmar, UNOPS.

LIFT. 2013d. *Lessons learned from livelihoods interventions in the dry zone of Myanmar.* Draft report. Yangon, Myanmar, UNOPS.

LIFT. 2013e. Dry zone programme formulation concept note. Livelihoods and Food Security Trust Fund (LIFT). UNOPS.

National Commission for Environmental Affairs in Myanmar (NCEA). 2007. *Environmental performance assessment in Myanmar*. Nay Pyi Taw, NCEA.

United Nations Development Programme (UNDP). 2011. *Addressing climate change risks on water resources and food security in the dry zone of Myanmar.* Ministry of Environmental Conservation and Forestry, United Nations Development Programme.

United States Agency for International Development (USAID). 2013a. *Strategic choices for the future of agriculture in Burma*. Summary paper by Michigan State University (MSU), and Myanmar Development Resource Institute, Center for Economic and Social Development (MDRI/CESD).

USAID. 2013b. *Working paper: A strategic agricultural sector and food security diagnostic for Myanmar.* Draft prepared for USAID/Burma by Michigan State University (MSU) and the Myanmar Development Resource Institute's Center for Economic and Social Development (MDRI/CESD).

Vokes, R. & Goletti, F. 2013. Agriculture and rural development in Myanmar: Policy issues and challenges. Agrifood International.

World Bank (WB). 1994. *Burma groundwater irrigation project i - project completion report.* Report No. 12891. Agriculture and Natural Resources Operations Division, Country Department I, East Asia and Pacific Regional Office.

WB. 2012. *Emergency project paper on a proposed pre-arrears clearance grant.* National Community Driven Development Project. Report No: 72460-MM. East Asia and Pacific Region.

World Food Programme (WFP). 2011. *Food security assessment in the dry zone Myanmar.* Food Security Analysis Services (ODXF).

ANNEX 2: PROPOSED INTERVENTIONS AND INVESTMENTS IN THE AGRICULTURAL WATER AND SOIL MANAGEMENT SECTOR

Intervention 1: Monitoring of groundwater resources

Justification	Groundwater resources in Myanmar appear to be relatively abundant and have ample scope for development. Groundwater is of particular importance in the CDZ where many people depend upon it for domestic water supplies and for irrigation. Sagaing region has 21,000 ha, Mandalay 7,000 ha and Magway nearly 4,000 ha irrigated from shallow and deep tubewells. However, a study of the CDZ by IWMI[10]in 2013 found groundwater to be a more moderate resource than estimated in some earlier surveys, with about 4.7 km^3y^{-1} available. The IWMI report states that, whilst extremely important for the CDZ, groundwater must be planned and developed carefully to ensure availability in the long term. Groundwater systems are dynamic and adjust continually to short-term and long-term changes in climate, groundwater withdrawal and land use. Resources need to be carefully protected to ensure that withdrawal rates do not exceed recharge rates. Reductions in groundwater storage can have major implications for water quality because the salinity of the groundwater frequently increases as the volume of the aquifer decreases. Once modified or contaminated, groundwater can be very costly and difficult to restore. Information is needed on the hydrological stresses acting on aquifers and how these stresses affect groundwater recharge, storage, discharge and quality. Long-term systematic measurements of water levels and water quality are essential to evaluate changes in the resource over time, to develop groundwater models and forecast trends, and to design, implement and monitor groundwater management and protection programmes. In addition, the models can play a central role where conflicts over groundwater resources or their management emerge. Design of a monitoring programme is a complex exercise that requires knowledge and experience. The World Bank AIRBM groundwater study should provide a range of information helpful to the initial design of the monitoring system. Nevertheless, designing a monitoring programme is an iterative process in which the final product will result from considering and weighing different options. As experience with groundwater monitoring is limited in Myanmar, the monitoring programme should start in a relatively small area and then be gradually extended as experience is gained. A gradual approach will provide insight into the labour and costs involved in

[10] IWMI. 2013. *Water resource assessment of the dry zone of Myanmar.* Final report. Livelihoods and Food Security Trust Fund /UNOPS.

	the final realization of the monitoring programme. The objectives of groundwater monitoring are: (i) collecting, processing and analysing the data as a baseline for assessment of the current state, anticipating changes and forecasting trends in groundwater quantity and quality due to natural processes and human impacts in time and space; and (ii) providing information for improvements in the planning, policy and management of groundwater resources. The following conditions are considered essential for successful monitoring: a. A legal, regulatory, institutional and technical framework that allows for sustainable management and protection of groundwater resources. b. Since irrigation is likely to be the major user of groundwater, responsibility for groundwater monitoring should lie with WRUD. Some groundwater monitoring tasks may be delegated, but final responsibility should lie with WRUD. c. The capacity of WRUD must be adequate to fulfil the task. Sufficient and suitable trained personnel, technical infrastructure, logistics and funding have been made available. d. Monitoring must be coordinated with all other institutions working in the field of water resources management. e. Data exchange structures are needed to optimize the benefit for all parties involved. The results and conclusions drawn from groundwater monitoring should made public at regular intervals.
Priority	Design of the groundwater monitoring and data management system in the short term (< 5 years) Monitoring of groundwater will be ongoing and long term
Scope	The first step is design of the groundwater monitoring and data management system. Once the design process is complete and various options have been considered is needed, that comprises an extensive monitoring networks supported by appropriate data collection protocols and modern easily accessible databases and analyses tools.
Activities	The proposed procedure for designing the groundwater monitoring and data management system involves: a. A preliminary assessment of the groundwater situation, the problems and trends, and the potential scale of a sustainable groundwater monitoring programme. This step is to assist in evaluating where systematic groundwater monitoring is most

	desirable and what the objectives and scope of the monitoring programme should be, considering the given budgetary and organisational conditions. b. Analysis of the groundwater system and development of a conceptual model. This step involves analysis of the groundwater system (aquifer and flow systems) and development of a conceptual model on the basis of available hydrogeological and hydrological information. The conceptual model, in turn, forms the technical framework for the groundwater monitoring network design. Groundwater quality is also analysed in relation to the groundwater flow systems defined. c. Analysis of the institutional setting, including (i) an inventory of the institutions involved in groundwater exploitation, management and protection; and (ii) analysis of their roles, mandates, tasks and related budgets and manpower. This should lead to a better idea of the scope and limitations related groundwater monitoring. d. An inventory of data needs and specification of monitoring objectives which includes listing the users of groundwater data and assessing their data needs. Monitoring objectives may include provision of data for assessment, development, management and protection of groundwater resources. e. Design of groundwater monitoring programme components for identified objectives. Each monitoring objective leads to a monitoring component with its own specific requirements (area to be covered, preferential network set-up, parameters needed, frequency of sampling, etc.). f. Specification of monitoring programme options, as the feasibility of a monitoring programme depends among other things on the budgets and institutional capacity available. Options may differ with respect to the scope of the programme, the area covered or the properties involved (e.g. network density, frequency of observation, etc.). Specification of the options to be considered should be done in consultation with representatives of the institution responsible for groundwater management. The details of the programmes considered should be clearly specified in maps and/or tables. g. Specification of the required budget, expected performance and necessary institutional capacity for each option considered. To prepare for the selection process, further analysis requires for each monitoring programme option considered:

	- Calculation of investments and annual costs involved in the monitoring programme; - Description of the information level expected (areas covered, objectives covered, estimated accuracy, etc.) - Analysis of institutional capacity needed and of possible limitations. h. Evaluation of feasibility of the monitoring programme options and selection of best option. Once the preferred option has been selected and resources have been guaranteed for a number of years, implementation of the preferred option can be initiated. Existing wells can form the basis for a groundwater monitoring programme, especially in the early stages. Monitoring plans should take existing wells and their locations, suitability of their design and maintenance/rehabilitation requirements into account. However, the technique used to install a well can influence the accuracy and reliability of groundwater monitoring. Specially drilled monitoring wells will be needed in the long run to ensure good network coverage and these are likely to produce more accurate data.
Expected duration	Designing the monitoring system could be undertaken in collaboration with the World Bank AIRBM groundwater study. It may take a year to reach the stage where implementation of the preferred groundwater monitoring option can be initiated. Once initiated monitoring of groundwater will be on-going and long term
Cost	TBD

Intervention 2: Improving the capacity of MoAI for irrigation and flood protection service delivery

Justification	The Ministry of Agriculture and Irrigation covers all aspects of agriculture and irrigation. Under the MoAI, the Irrigation Department (ID) is responsible for all gravity irrigation systems, flood control infrastructure and drainage, while the Water Resources Utilization Department (WRUD) undertakes all pumped irrigation schemes, whether from rivers or from groundwater. Whilst the ID is relatively strong on the infrastructure development side of irrigation and flood control, and WRUD has well trained mechanical engineers, geologists and soil specialists, neither department has skills in irrigation agronomy, irrigation water management, participatory management and development, or environmental protection. In addition, WRUD is understaffed and has no civil engineers to develop the irrigation canal systems to distribute pumped water. Both departments suffer from budget constraints that effects both the standard of initial infrastructure constructions and the operation and maintenance of schemes. Many schemes combine both gravity water distribution systems and pumping. Consideration should be given to improving the efficiency of irrigation and flood control intervention delivery through amalgamating the ID and WRUD into one department (perhaps renamed the Irrigation and Flood Control Department). The department's capacity for efficient irrigation service delivery would be improved through upgrading the skills of staff at central, regional and project level in modern irrigation technologies, improved design, management, operation and maintenance of irrigation systems and extending the range of skills available through the recruitment of staff with expertise in irrigation agronomy, irrigation water management (including water use efficiency), participatory irrigation management and development, and environmental protection. Irrigation schemes that are being rehabilitated and upgraded can be used for practical training exercises.
Priority	Short term < 5 years
Scope	Amalgamate the ID and WRUD into one department, perhaps called the Irrigation and Flood Control Department. Extend skills available within the department to include irrigation agronomy, irrigation water management (including water use efficiency) and participatory irrigation management and development, and environmental protection and management. Provide support to the Irrigation Technology Centre (ITC) to improve their capacity for training ID/WRUD staff in these topics. Provide capacity building for ID/WRUD staff to improve scheme designs, water use efficiency, farmer participation, irrigation

	agronomy, on-farm water management, etc.
Activities	The proposed activities include: a. Improve office premises at central and regional level for new department to provide adequate space for the combined ID/WRUD officers & additional staff. Provide additional vehicles, furniture, equipment, etc. b. Recruit additional staff with experience in irrigation agronomy, irrigation water management (including water use efficiency) and participatory irrigation management and development, and environmental protection and management. c. Provide support to the Irrigation Technology Centre (ITC) to improve their capacity for training irrigation staff in topics such as improved scheme designs, water use efficiency, farmer participation, irrigation agronomy, on-farm water management, environmental protection. d. Provide capacity building for irrigation staff through: - ITC courses that include practical training exercises on irrigation; schemes that are being rehabilitated and upgraded; - workshops and seminars; - study tours to other countries in the region.
Expected duration	4 – 5 years
Cost	Costs are very rough at this stage. Improving premises for combined ID/WRUD & additional staff, additional vehicles, furniture, equipment, etc. — US$ 500,000 Salaries of additional staff for 3 years — US$ 400,000 Support to ITC — US$ 300,000 Training courses and workshops — US$ 600,000 Study tours for staff to other countries in the region — US$ 200,000 TOTAL — US$ 2,000,000

Intervention 3: Rehabilitation and extension of existing MoAI irrigation systems

Justification	In 2012/13 the area under irrigation was about 2.1 m ha, with about 23% of the area double cropped. The government gives irrigation development a high priority in order to increase crop yields and cropping intensity. This is reflected in the large share of the development budget allocated to the construction and maintenance of irrigation schemes under current and proposed plans for the agriculture sector. The urge to move forward with irrigation developments as quickly as possible has compromised the quality and sustainability of some projects implemented in the last 15 to 20 years. Many existing irrigation schemes function below their potential due to a poorly developed systems and inadequate management, operation and maintenance. Reported problems with irrigation systems include inappropriate design that prevents adjustment of water supply according to variations in demand over seasons, incomplete tertiary canals and on-farm networks, unlined canals with high seepage rates, lack of land levelling, inappropriate crop choice and irrigation method for the type of soil, and lack of maintenance and monitoring. Soil salinity and sodicity due to waterlogging, or to the use of poor quality groundwater for irrigation, has reduced yields considerably in parts of a number of schemes, particularly in the CDZ. In some cases, land that produced reasonable yields under rainfed conditions has been abandoned, or produces very poor crops, as a result of the introduction of irrigation. A focus on the rehabilitation and upgrading of existing irrigation schemes, as opposed to new construction, will allow rapid improvement of crop production under irrigation and extension of irrigated areas at relatively low cost since the basic structures already exist. Also, there will be few safeguard concerns since construction and development will take place mainly on existing sites. With improved management and a change in cropping patterns to non-rice crops it will be possible to expand the cropping areas and cropping intensity. The CDZ should be a focus of support because: (i) it is the second most densely populated region of Myanmar after the Ayeyarwaddy delta and has higher levels of poverty; (ii) it is a traditional agricultural area and improved irrigation would significantly strengthen productivity and output; (iii) the cost would be relatively low as the main structures have already been constructed; and (iv) there is ample potential for improving and extending irrigation. The selection of schemes for rehabilitation and extension should be based on: (i) their potential for increased crop production and poverty reduction, (ii) the condition of the existing system and the likely costs of improvements, (iii) possible environmental and social impacts – there should be no significant adverse environmental or social impacts, and no conflicts over land or water resources; and (iv) the implementation

	capacity of MoAI, bearing in mind that organizations such as WB, ADB, JICA and IFAD are supporting major irrigation development. (IFAD and the World Bank are coordinating their respective investments, and the World Bank is considering using similar irrigation management and advisory services arrangements to those being set up under IFAD's Fostering Agricultural Revitalization in Myanmar Project)
Priority	The need for this intervention is long term. In the short term, major WB, ADB, JICA and IFAD irrigation projects are just beginning and are likely to stretch the capacity of existing irrigation staff.
Scope	The intervention will build on the experience of the WB, ADB, JICA and IFAD irrigation programmes that are just starting. It will support the rehabilitation, upgrading and extension of existing MoAI irrigation systems, improvements to water use efficiency, the strengthening of farmer participation in operation and maintenance, and more attention to improving crop production and farmer incomes. The optimum investment and number of schemes to be covered cannot be estimated at this stage.
Activities	Activities proposed under this intervention include: a. A review of irrigation activities and lessons learned from the WB, ADB, JICA and IFAD irrigation rehabilitation projects that are starting in 2014/15. b. A rapid appraisal of MoAI irrigation schemes in the CDZ to identify key issues and problem areas, options for improvements and a preliminary estimate of their costs. For each scheme it should cover: (i) the history of the system; (ii) the physical system, including hydrology, canals, structures, drainage, soils; (iii) management operation and maintenance; (iv) institutions and social environment; (v) agriculture and agricultural services; and (vi) areas requiring further investigation c. Based on the rapid appraisal, the selection and prioritization of irrigation schemes for rehabilitation, upgrading and extension. d. Implementation of measures which may include: - Inspection and, if needed, improvement and rehabilitation of existing dams, reservoirs, weirs and other structures serving the irrigation system; - Rehabilitation/upgrading of the irrigation canal system and structures to tertiary level, including canal lining where seepage is an issue. Provision of water division and water measurement structures throughout the system and improvements to the layout of farm plot to make water distribution easier, and with a view to water taxes based on water volume instead of land area at some future time; - Where electricity becomes available, replacement of diesel

	engines powering pumps with electric motors that have much lower running costs; - Where adequate water is available, extension of the canal system to irrigate additional land; - Upgrading or provision of drainage systems, especially in saline areas; - Provision or improvement of farm roads; - Land levelling; - Strengthening Water User Groups, Water Management Committees and participatory operation and maintenance of the irrigation system. This includes introducing clear rules and regulations setting out the rights and responsibilities of stakeholders, particularly in the areas of water allocation, distribution and use, maintenance and water charges. - Provision of water management and irrigation agronomy training to both irrigation staff and farmers. - Reviewing and improving crops, cropping patterns and agricultural techniques through improved extension and inputs such as good quality seed and fertilizer.
Expected duration	Rehabilitating and extending existing irrigation systems will be long term, starting in about 2017/18.
Cost	The WB Agricultural Development Support Project has a budget of USD 100 million over 7 years for (i) Irrigation and Drainage Management (USD70 million); (ii) Farm Advisory and Technical Services (USD23 million); (iii) Project Coordination and Management (USD7 million); and (iv) Emergency Contingency Response (US$0 million). It is estimated that the project will target rehabilitation of 7-8 irrigation schemes over its life. The WB has calculated an average cost for irrigation rehabilitation of USD 1,250/ha (See the WB PER database). If USD 100 million was made available under NAPA for rehabilitation and extension of existing MoAI irrigation systems, then irrigation and crop production on 80,000 ha of land could be improved, assuming a cost of USD 1,250/ha. In addition, a budget of USD 15 million – USD 20 million would be needed for personnel, offices, equipment, transport, contingencies, etc.

Intervention 4: Development of small-scale community-managed irrigation schemes

Justification	In Myanmar the government has concentrated on developing large irrigation systems and limited attention has been given to providing support for small-scale community run schemes, or to assisting individual farmers to develop irrigation. Small-scale irrigation[11] has been a component of some donor funded livelihood based and community development programmes. NGO have assisted the development of a few small community schemes and have trialled the use of treadle pumps, sprinklers, drip irrigation and hydroponics. Due to their technical complexity and the high investment required, most farmers are still reluctant to try such technologies, but some private companies and better off farmers use sprinklers. Some communities and many individual farmers have developed small areas of irrigation without outside assistance. It is estimated that private irrigation covers about 245,000 ha at present. Small community schemes tend to provide supplementary water, particularly for rice, rather than full irrigation and draw water from village ponds, diversion of flood flows, small weirs on streams or by pumping from surface water sources or groundwater. There is little information on the performance of these systems, but those seen during field visits were mainly producing food crops for home consumption, with a small surplus for marketing. Pumping technologies have become cheaper and more accessible in recent years and many individual farmers are buying or renting pumps to draw water from shallow tubewells or surface sources. Sometimes within irrigation schemes tail end farmers, or those with slightly higher land out of command, pump from groundwater or nearby canals. Small scale, farmer managed pumping has significant advantages in terms of flexibility, reliability and simple operation and maintenance. Where good quality groundwater supplies are available and sustainable, this has proved to be an affordable and effective way to increase production. There is great potential for the development of more small schemes for groups of farmers taking water from surface sources or by pumping from shallow tube wells in areas with good quality aquifers, for irrigation of vegetables and oil crops such as sesame and sunflower. Community or individual farming household based schemes for harvesting rainwater and diversion of floodwater will support small farmers in enhancing their income through diversifying their farming practices through vegetable, livestock and fish farming in an integrated way. Diversification of food systems will also positive impact on family nutrition. This intervention may also be considered as pro-women.

[11] Small-scale irrigation is often defined as schemes of 200 ha or less.

	These could be assisted under stand-alone projects or as a component of a community development projects. In addition, individual famers could be supported through technical advice and credit to develop pumped irrigation. At present, water saving technologies such as sprinklers and drip irrigation are almost unknown and, sprinkler irrigation in particular, has the potential to play an important part in irrigated production (drip irrigation tends to be less popular with small farmers as it is expensive to install and, unless water is good quality, tends to suffer from frequent blockages). Under NAPA a small-scale irrigation development programme is recommended. Under the programme, the development of both small-scale community-managed irrigation systems and irrigation by individual farmers, using both surface and groundwater resources, should be encourage and supported. Farmers should be fully involved in all stages of development of irrigation systems and should bear the major part of the cost, with assistance provided to access credit. The role of the private sector in system development, equipment supply and support should strengthened, especially for groundwater systems. This will require funding and technical assistance from a major aid agency for up to 10 years and involvement of NGO.
Priority	Short term and long term
Scope	The CDZ should be the initial focus of the programme, but there is scope throughout the country for the development of small community and individual farmer irrigation systems. Over 10 years it may be possible to develop 20,000 ha or more of small scale irrigation systems operated by groups of farmers or individuals.
Activities	Activities proposed under this intervention include: a. Preparation of proposals for a small-scale irrigation development programme; b. Recruitment of TA, both international and local; c. Initiation of the programme in the CDZ with activities including: - Identification of locations for investment where the potential for irrigated agriculture is good and farmers interested; - Development of models for small-scale irrigation, including shared investment between small groups of farmers, investment by individual farmers, supply of water by private investors, assistance from NGOs with community and group development activities and the introduction of new technologies; - Encourage private sector involvement and investment in small scale irrigation systems, including the provision of technical advice, credit for equipment, and, in some cases, developing

	irrigation systems and charging farmers for water; - Support for loans to groups and individuals for development of irrigation, including well drilling, pumps and equipment; - Capacity building for farmers including study tours to see examples of successful small scale irrigation in other parts of the country, assistance with group formation and training in skills such as bookkeeping, irrigation agronomy training; - Support for construction of the irrigation system in the form of technical advice and providing links to companies for well drilling, and provision of irrigation equipment and services; - Assistance with access to good quality seed and inputs; - Provision of irrigation agronomy advice to assist farmers in making the best and most efficient use of irrigation through their choice of crops, timing of planting and in-field water management (use of furrows, sprinklers, mulching, etc.); - Assistance with market linkages. d. Extending the programme to other parts of the country, once the initial activities have proven successful.
Expected duration	10 years
Cost	A very rough estimate is USD 3 million – USD 4 million

Intervention 5: Upgrading of flood control structures in the Ayeyarwaddy Delta

Justification	Much of the low-lying Delta Region is subject to flooding, storm surges, and salinity intrusion, resulting in crop losses and reduced yields. In 2008, about 140,000 people died and as many as 2.4 million people were affected by Cyclone Nargis. In the Ayeyarwaddy Delta, nearly 700,000 ha of good cropland is protected by over 2,000 km of embankments and drainage channels, including sea dykes in coastal areas to protect the land from salt water intrusion. River embankments are also found in the upper Ayeyarwaddy River Basin, especially near Mandalay, where adverse land slopes leave land prone to flooding. Many of the structures in the delta were badly damaged by Cyclone Nargis which affected 50 townships, mainly in Yangon and Ayeyarwaddy regions. Rehabilitation is still ongoing leaving some of the most productive part of the country vulnerable to floods. Flood control and drainage infrastructure will become increasingly important in the presence of global climate change. Weather patterns are increasingly difficult to predict, with drought one year and flooding the next. Most formal assessments suggest that climate change will affect Myanmar significantly. Major expected changes include rising temperatures, higher rainfall and a possibly a shorter rainy season, and an increase in severe cyclones along the coastline, which in combination will contribute to a considerable increase in flooding. Rising sea levels along the coast are likely to compound these problems by aggravating salt water intrusion and soil salinity in the coastal areas and river deltas. Myanmar needs to improve its ability to manage its increasingly unpredictable fresh water flows and minimize salt water intrusion near the coast. Investments in improved water control infrastructure is fundamental to protecting agricultural land and the population in flood-prone areas, particularly in the fertile Ayeyarwaddy and Sittaung deltas. Budget constraints mean that at present most flood defences are only being maintained to a minimal level, increasing the risk of flooding and salt water intrusion. Over the next 20 or 30 years it is essential that they are improved - raising the height of embankments and strengthening them, replacing or repairing sluice gate, renovating or constructing drains, and protecting riverbanks. The government would need to make commitment to increase the operation and maintenance budget for flood control infrastructure considerably to maintain the condition of existing structures and ensure the sustainability of rehabilitated and upgraded structures. At present, flood control structures provide protection from all but the worst storms. There is still time to reduce the potential for catastrophic floods in the future, by improving flood protection infrastructure.

	Embankments, sluice gates, drains and other flood control measures need to be surveyed to determine rehabilitation and improvements required, both in the short-term and in the long-term. Proposals should be prepared for phased implementation of the required works over the next 20 to 30 years.
Priority	Short term (< 5 years)– survey of existing flood control infrastructure and preparation of a programme of infrastructure rehabilitation and upgrading. Long term (> 5 years) Rehabilitation and improvement of existing infrastructure and provision of additional structures where needed.
Scope	Survey to determine the condition of existing flood control infrastructure to determine improvements needed to existing structures and additional measures needed. This will involve mainly the 2,000 km of embankments in the Ayeyarwaddy Delta. Rehabilitation and improvement of existing infrastructure and provision of additional structures where needed. This will involve mainly raising the height and strengthening much of the 2,000 km of embankments in the Ayeyarwaddy Delta.
Activities	The main activities required include: a. A survey existing embankments, sluice gates, riverbank protection and drainage to determine work needed in the short and long term (taking possible effects of climate change into consideration). b. Based on the survey results, preparation of a phased programme to undertake the required rehabilitation and improvements to flood control infrastructure; c. Implementation of rehabilitation and improvement works would start with the most urgently required works, and then continue to improve infrastructure to protect against the likely effects of climate change.
Expected duration	3-4 years for the survey. 10-20 years for rehabilitation and improvement of flood control infrastructure
Cost	USD 3 million for the survey A minimum of USD 100 million for the works required.

Intervention 6: Participative, community-based soil and water conservation activities

Justification	Land degradation, particularly soil erosion in upland agricultural areas and dry zones, is an increasing problem in Myanmar. The main causes of land degradation include deforestation, poor agricultural practices, overgrazing and shifting cultivation, all of which are exacerbated by the increasing population, particularly in the upland areas. About 10% of total cultivated land in the country is estimated to be vulnerable to severe soil erosion, with Shan State, Chin State, and Sagaing Region amongst the most badly affected areas. Degraded farm land, as a percentage of total cultivated area, was estimated at 33% in 2008. The Government capacity to implement soil and water conservation measures and to reclaim degraded land is limited by a lack of commitment at higher levels of government, and insufficient expertise and funding. Whilst donor funded projects have emphasized the need for a catchment-wide conservation approach, in practice resources have been spread too thinly and the tendency has been to work with just the poorer villages, excluding better off villages in the same catchment. In Myanmar the emphasis is still on physical, rather than vegetative, techniques for control of runoff and erosion. Techniques such as terracing often do little to increase production or incomes and have a high labour requirement. The main emphasis should be on promoting biological conservation and moisture retention techniques which make the best use of water where it falls, increase vegetative cover and generally improve soil structure and water holding capacity (e.g. Conservation Agriculture). In drier areas such as the CDZ, however, where it is more difficult to implement vegetative methods, physical methods may be needed to help plants to become established and cover the ground quickly. Due to inadequate budgets and staff, soil conservation activities on agricultural land undertaken by the Land Use Division (LUD) of MoAI and the Ministry of Environmental Conservation and Forestry (MOECF), are mainly limited to small demonstration plots, sometimes carried out in cooperation with local farmers. Field days for farmers are held on these plots occasionally, but government officers complain that famers are reluctant to copy the techniques unless paid. This is particularly evident in the watershed surrounding Inle Lake in Shan State, an important tourist resource, where there is considerable concern about high siltation rates. The main emphasis of MOECF has been on tree planting on the surrounding slopes. However, much of the watershed is agricultural land, including areas of shifting cultivation, and in these areas efforts to control soil erosion appear to be limited entirely demonstration plots. ICIMOD has recently started funding soil conservation activities in this area, again mainly in the form of

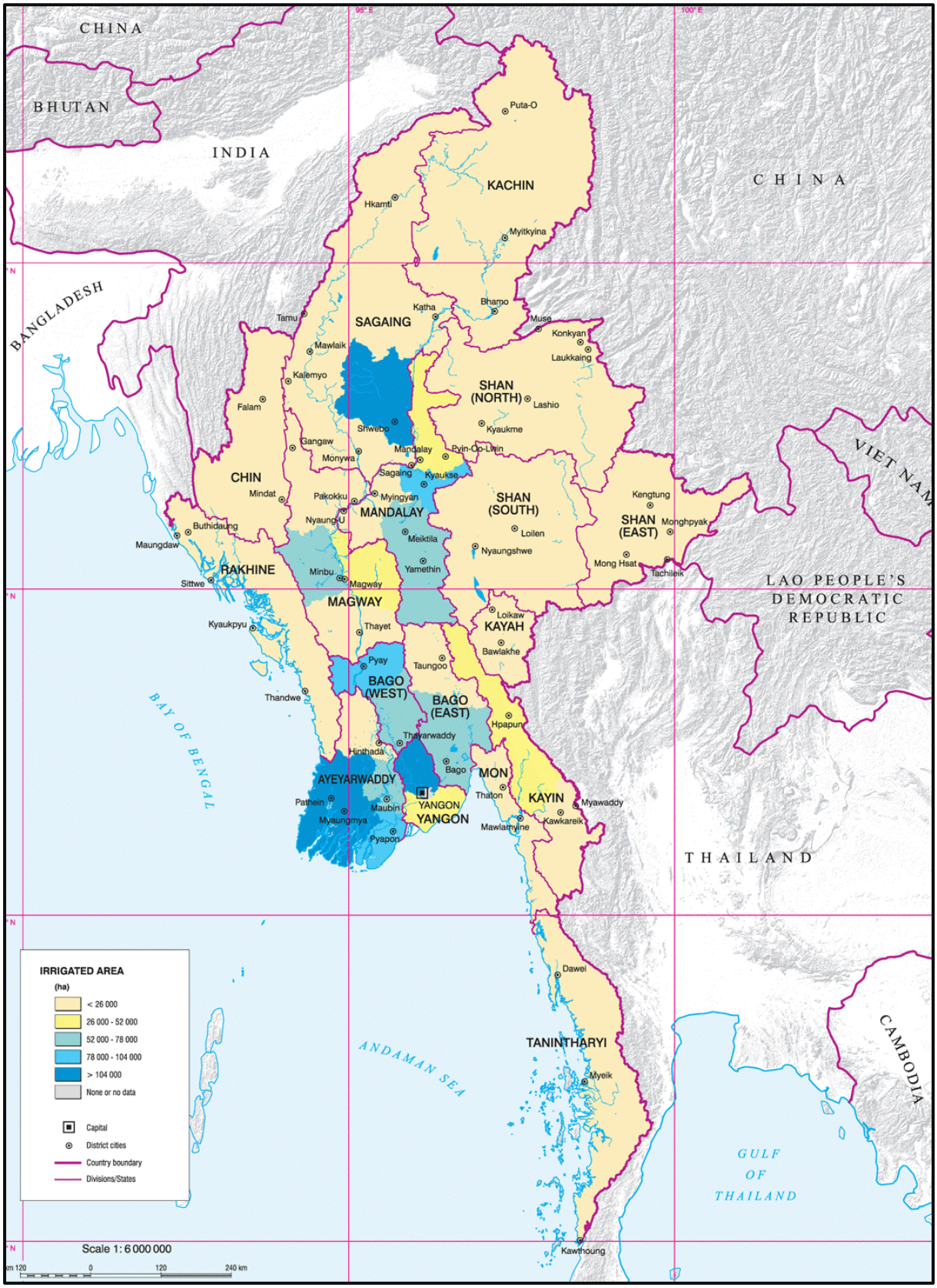
	demonstration plots. Although not a priority with communities, soil and water conservation is important for: (i) reducing and repairing land degradation; (ii) protection of infrastructure from erosion and sediment damage; and (iii) managing water effectively in rainfed systems at both field and watershed scales.
Priority	Short term – preparation of catchment watershed protection programmes Long term – implementation of watershed protection programmes
Scope	This activity will mainly cover the poorer areas in the CDZ and uplands, particularly areas where erosion is damaging valuable assets such as reservoirs. A watershed approach to erosion control and water harvesting should be taken, with a view to improving crop production potential and the sustainable development of agriculture. Availability of water in small impoundments, ponds and pools will support livestock and fish culture which are likely to encourage the communities to follow a sedentary habit.
Activities	The main activities will include: a. Preparation of a proposal for participative, community based soil and water conservation activities on a watershed basis; b. Identification of priority watersheds for activities in cooperation with Land Use Division of MoAI, and the Environmental Conservation and Dry Zone Greening Departments of MOECF and preparation of a long term watershed protection programme; c. Recruitment of TA, both international and local, for implementation of the programme; d. Strengthening the capacity of the Land Use Division of MoAI, and the Environmental Conservation and Dry Zone Greening Departments of MOECF in soil and conservation techniques and community mobilization; e. Training of agricultural extension staff in soil and conservation techniques, particularly Conservation Agriculture. f. Implementing the programme, starting with watershed in the poorest areas and where valuable assets such as reservoirs and roads are threatened by soil erosion and siltation. The main emphasis should be on promoting biological conservation and moisture retention techniques which make the best use of water where it falls, increase vegetative cover and generally improve soil structure and water holding capacity (e.g. Conservation Agriculture). In drier areas such as the CDZ, however, where it is more difficult to

	implement vegetative methods, physical methods may be needed to help plants to become established and cover the ground quickly. Cash-for-work programmes may be needed A regulatory approach to conservation is generally ineffective - farmers are more likely to respond to incentives and technical assistance. In the past, incentives provided by aid agencies have often been counterproductive with a slow pace of work, follow-up maintenance neglected and, in some cases, conservation works constructed but then not used. Nevertheless, careful use of incentives is essential to encourage villagers to participate in conservation activities. These should be kept to a minimum and only used for works benefiting the community as a whole such as the planting of trees, for community groups testing new techniques, and for conservation measures on public land. They should be in the form of the provision of materials and tools, funding of transport or equipment hire, and payment for a portion of the labour involved. Where cash-for-work is used, every effort should be made to employ the poorest members of a community.
Expected duration	Up to 20 years
Cost	TBD

ANNEX 3: MAPS

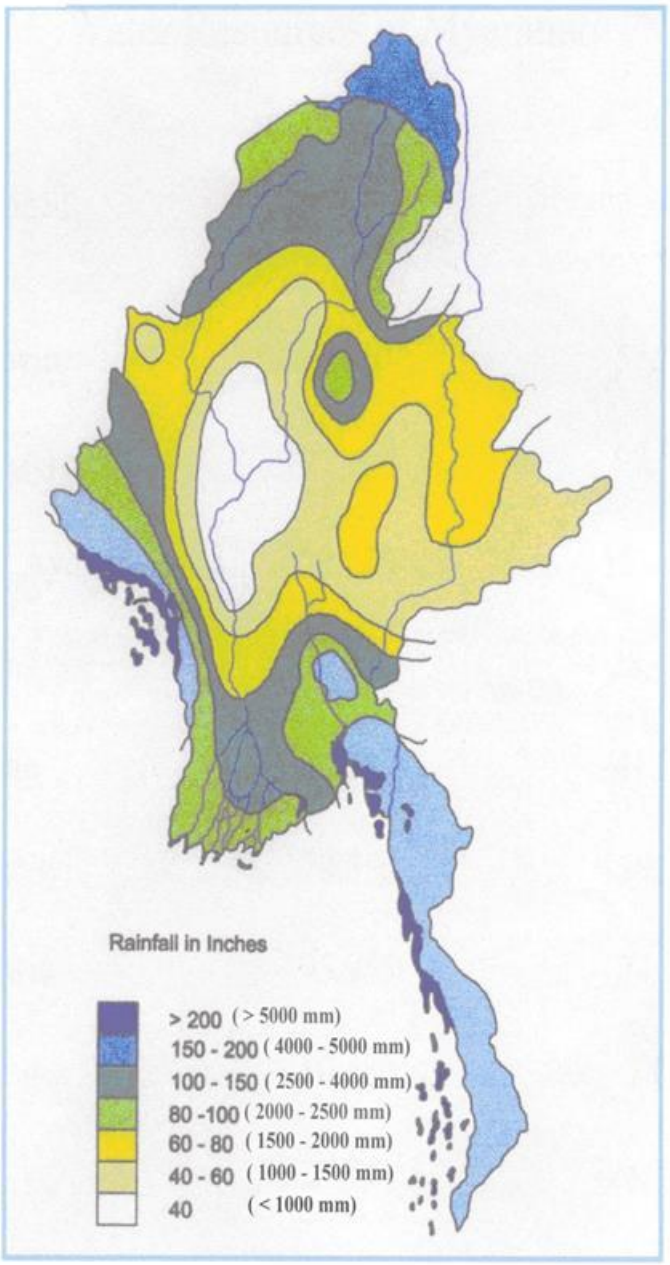
Map 1: Map of Myanmar showing topography

Map 2: Distribution of irrigation and flood control works in Myanmar

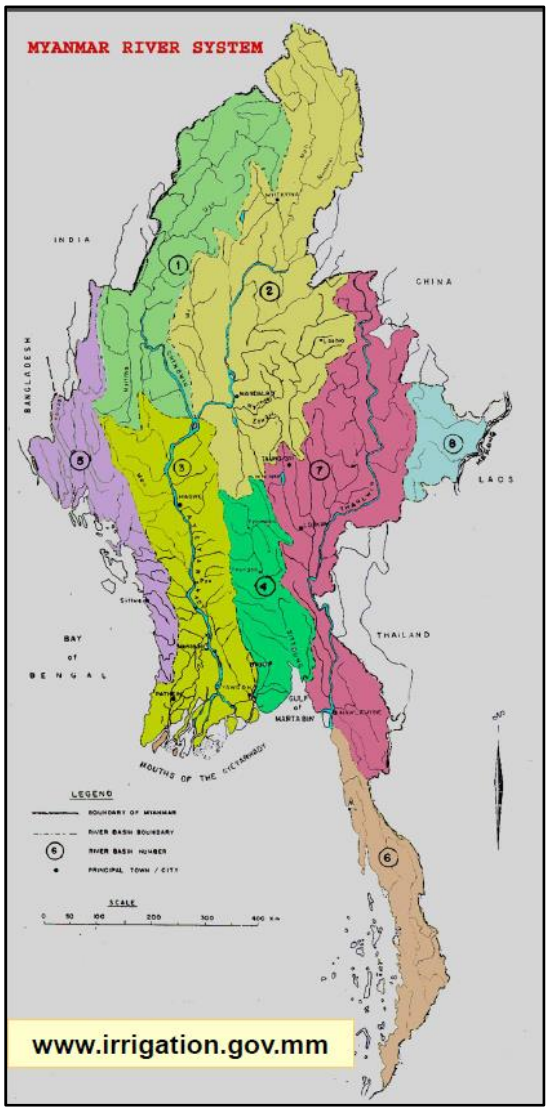


Map 3: Rainfall distribution in Myanmar

Rainy season	May – October
Cold season	November - January
Dry season	February – April



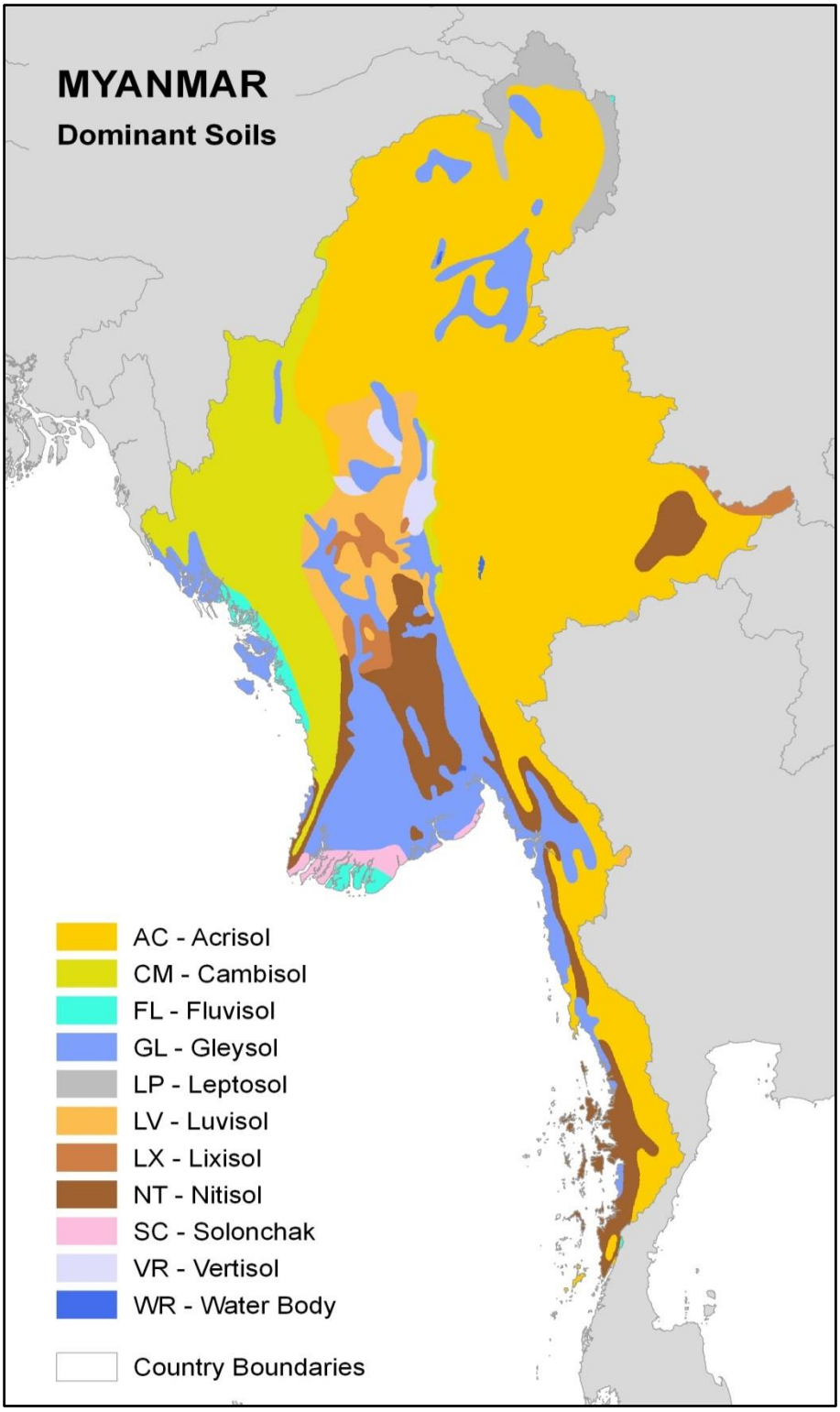
Map 4: Catchments and water resource potential of Myanmar



No.	Name	Catchment area (10^3 km^2)	Est. average annual surface water (km^3)	Est. groundwater potential (km^3)
1	Chindwin	115.30	141.29	57.58
2	Upper Ayeyarwaddy	193.30	227.92	92.60
3	Lower Ayeyarwaddy	95.60	85.80	153.25
4	Sittoung	48.10	81.15	28.40
5	Rakhine	58.30	139.25	41.77
6	Taninthari	40.60	130.93	39.28
7	Thanlwin River	158.00	257.93	74.78
8	Mekong	28.60	17.63	7.05
	TOTAL	737.80	1081.88	494.71

Source: Ministry of Agriculture and Irrigation. 2011

Map 5: Soils of Myanmar



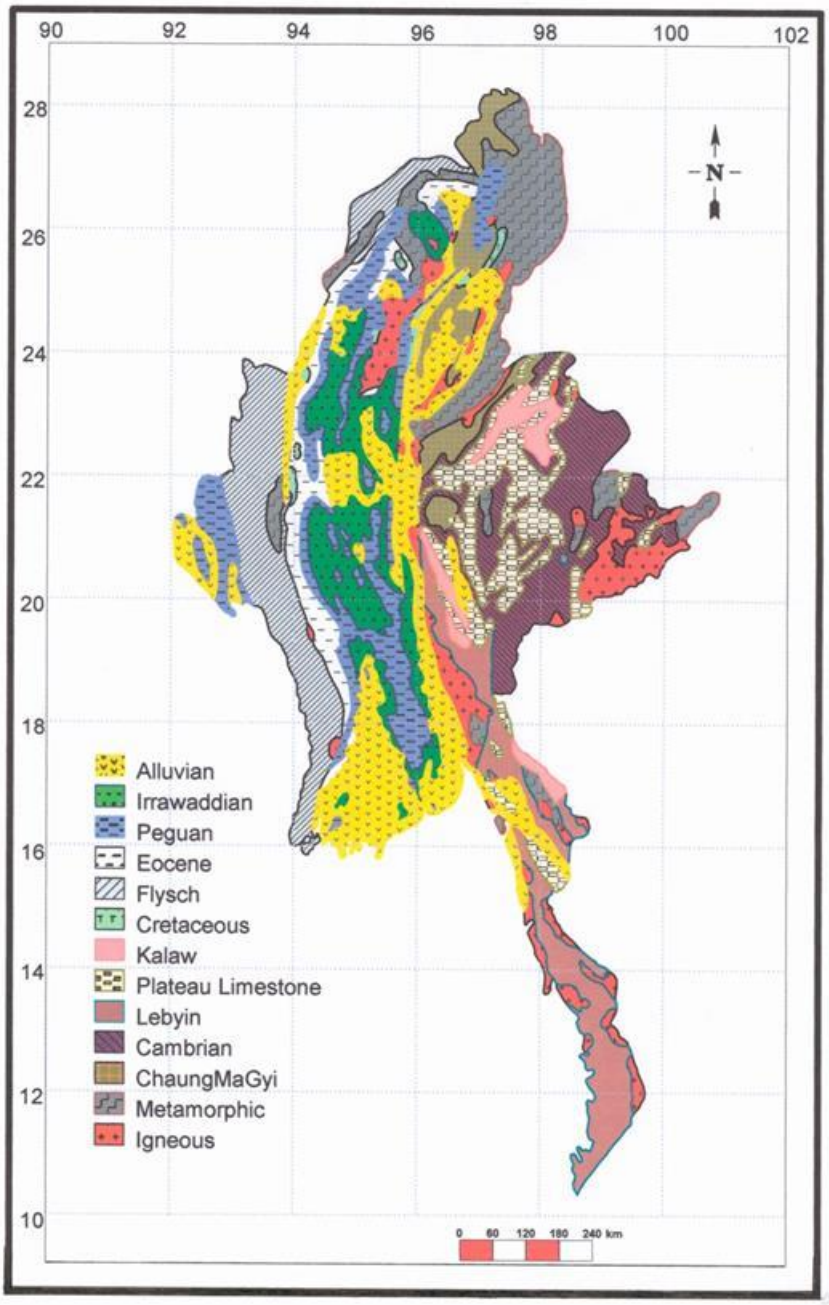
Map 6: The major aquifers of Myanmar

On the basis of stratigraphy, there are 11 different types of aquifer in Myanmar.

Depending on their lithology and depositional environments, ground-water from those aquifers have disparities in quality and quantity.

Groundwater quality of Alluvial and Irrawaddian aquifers is good and suitable for both irrigation and domestic water use.

In the water scarce regions, groundwater from Peguan, Eocene and Plateau Limestone aquifers are used for domestic purposes, although they are not totally safe for drinking and are likely to cause soil salinity/sodicity if used for irrigation.



ANNEX 4: ORGANIZATION CHARTS FOR THE IRRIGATION DIVISION AND THE WATER RESOURCE UTILIZATION DEPARTMENT

Figure 1: Organization chart of the Irrigation Division

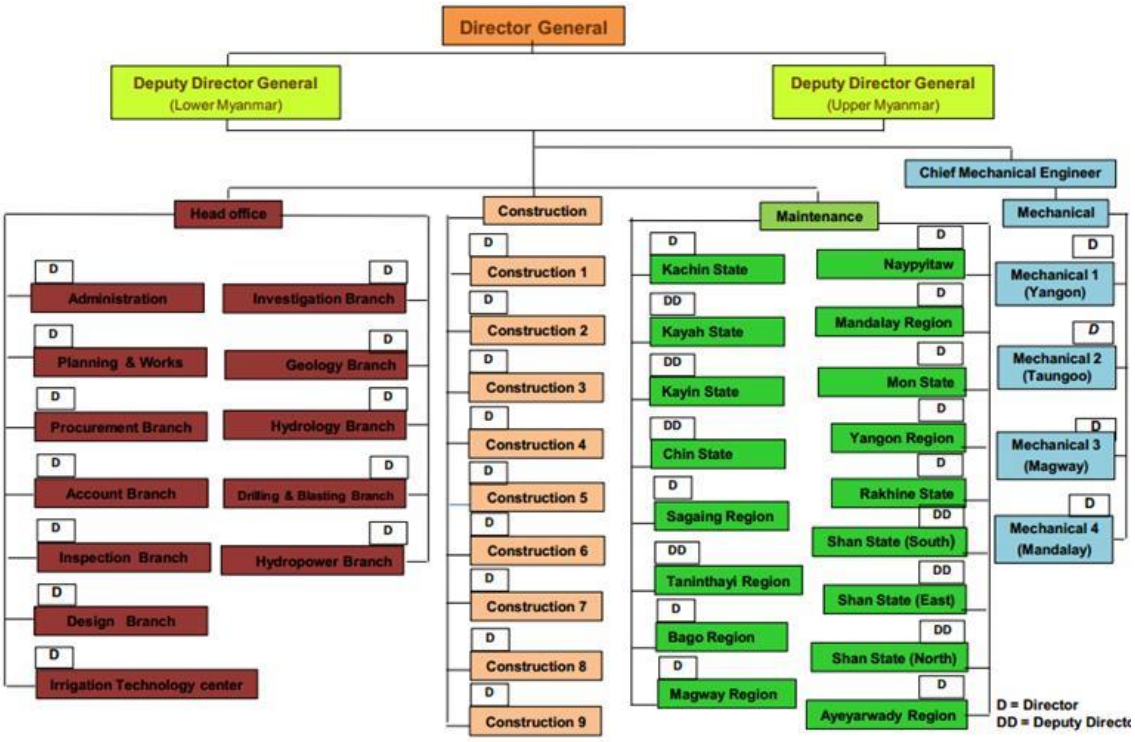


Figure 2: Organization chart of the Water Resource Utilization Department