Livelihoods and Food Security Trust Fund

Identifying priority investments in water in Myanmar's Dry Zone

Final Report for Component 3

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Acronyms

DDA	Department of Development Affairs
DI	Department of Irrigation
ESCAP	Economic and Social Commission for Asia and the Pacific
FSWG	Food Security Working Group
GWI	Groundwater irrigation
INGO	International Non-Governmental Organization
IWRM	Integrated water resource management
JICA	Japan International Cooperation Agency
LIFT	Livelihoods and Food Security Trust Fund
MIMU	Myanmar Information Management Unit
MOAI	Ministry of Agriculture and Irrigation
NEPS	National Engineering and Planning Services
PSGF	Piped Water Supply by Gravity Flow
VWCs	Village Water Committees
WRUD	Water Resources Utilization Department

Summary

The report is the third in of a series of three reports being developed as part of an IWMI-led project investigating water resources and livelihoods in the Dry Zone of Myanmar. The overall objective of the project is to provide information on water resources and management which can serve as input to the formulation of a LIFT Dry Zone program, which will run from 2013 to 2016. The study had three main components:

- A water resources assessment (surface and groundwater) of availability and current use of water resources, and patterns, trends and variability at different spatial and temporal scales.
- Community survey to evaluate issues of water availability, access and management for different livelihood types in 24 local communities, including evaluation of institutional arrangements in relation to farming strategies and water management practices
- Review and analysis of existing program investments in water in the Dry Zone

This report synthesizes results, analyses existing investment patterns and outcomes, and makes recommendations for priority areas for future investment.

The heterogeneity of the Dry Zone in terms of physical environment, farming systems, access to water and infrastructure results in significant differences in development opportunities and priorities between villages, even over quite small distances. This means that there are no blanket solutions: the details of water-related interventions must be shaped with each community. It is important that water interventions are embedded into broader village livelihood strategies and take account of the full range of uses, rather than a focus on domestic supply separate to other needs. Existing studies and agencies working in the area emphasize that there is good understanding of issues and potential solutions within local communities and agencies. The need is not so much for new technologies, but for approaches to support implementation; and refinement and targeting of known technologies.

We propose consideration of water-related interventions in five domains; for each we have identified opportunities and priorities, as well as factors constraining implementation, knowledge gaps and potential entry points for LIFT.

Formal irrigation schemes: Even though the availability of water is not constraining, the effectiveness of existing formal irrigation is often low, due to a complex mix of physical, technical, policy and institutional challenges. It is recommended that before LIFT engages in major rehabilitation programs or construction of new irrigation schemes, an assessment is needed of issues impeding the effectiveness of current schemes.

Potential entry points for LIFT

- Working with government to clarify policies relating to irrigation and water resource management and how these align with agricultural development policies
- Assessment of the relative effectiveness of different modes of irrigation (gravity schemes, Pumped Irrigation Projects, groundwater) in terms of water and energy productivity as well as impacts on yields, farm incomes and livelihoods, at two levels: a comparative assessment across existing large schemes; and community based analysis of requirements and outcomes at village level.

- A trial of the 'golongan' system of water delivery management to rationalise water delivery in existing scheme, as an entry point for LIFT to work with government to better link water resources planning with crop planning.

Groundwater interventions: We recommend that groundwater investment should focus on two areas: securing village / domestic supplies using tube wells; and supporting development of small-scale supplementary irrigation. If properly located deep tube wells provide reliable, high quality water in all seasons for domestic use, with benefits for the whole community. Farmers are already adopting groundwater irrigation using shallow tube wells in rainfed areas, and also within irrigation command areas where there are shortfalls in supply. Our analysis suggests that an additional 110,000 to 330,000 ha of groundwater irrigation could be developed sustainably. A mix of technical and financial support is needed to overcome high establishment costs.

Potential entry points for LIFT

- Technical support, through WRUD and / or relevant NGOs to identify priority areas for groundwater use (based on resource assessment – see Section 5.5)
- An inventory (database and maps) of existing wells and utilization, including water quality data (salinity, arsenic)
- Support for motorised deep tube wells for village (domestic and livestock) supplies
- Business models for communities to install and operate village pumps for domestic supplies, including private investors, village water committees
- Program to promote use of shallow tube-wells for small-scale supplementary groundwater irrigation (GWI) for a range of cropping systems including rainfed areas, and conjunctive use to supplement shortfalls within irrigation schemes
    - Business models for small-scale GWI, including shared investment between small groups of farmers, and supply of water by private investors
    - Agronomic advice: extension services to help farmers make best use of irrigation through crop choice and in-field water management (e.g. drip irrigation, mulching etc)
    - Work with NGOs (e.g. Proximity) to develop and market appropriate and affordable pumps and equipment
- Microfinance or loans to communities and individuals for pumps and equipment
- Regional monitoring network, possibly using community monitoring of wells, as input to groundwater assessments (see Section 5.5)

Small reservoirs for rainwater harvesting and storage: emerge as the preferred option for improving water supplies for villages in many contexts in the Dry Zone. They are a simple, proven technology, but type, design and siting of such reservoirs are very specific to each location. Key constraints for effective adoption of small reservoirs are cost of construction; and commitment of communities to on-going maintenance.

Potential entry points for LIFT

- There is potential to scale up existing projects to construct and/or renovate village ponds, small reservoirs and sand dams, being implemented by NGOs including ActionAid, Solidarity International, Proximity and ADRA. Prior to scaling up, a preliminary review should be conducted of outcomes of the projects, including sustainability of structures and maintenance.

- Technical support and guidelines for improvements in design, including suitable soil types and locations, and ways to capitalise on the potential to use seepage from RWH structures to recharge shallow aquifers
- Watershed management programs in catchment areas of reservoirs to protect inflows and water quality.
- Economic analyses of costs involved in construction, maintenance, rehabilitation of RWH infrastructure and evaluation of existing RWH technology, including siltation and lifespan of the structures

Soil and water conservation: though not a priority from village consultations, are important in three contexts: reducing and repairing land degradation; protection of infrastructure from sediment damage; and managing water effectively in rainfed systems at both field and watershed scales. The emphasis is on working across scales to slow the movement of water through the landscape, to enhance infiltration and availability of water, and reduce erosion. The most serious constraints are getting the necessary buy-in from higher levels of government to coordinate programs across large areas; and developing mechanisms to motivate communities to participate in such activities.

Potential entry points for LIFT

- At farm scale, agronomic extension programs should include information and advice on SWC techniques; and targeted subsidies or incentives may be appropriate.
- At village scale: watershed management should form an essential component of pond construction and rehabilitation, with opportunities for local employment and income benefits.
- At watershed scale, LIFT could play a role in engaging Government (though Forestry Department and Irrigation Department) to evaluate and re-invigorate or redesign existing watershed management programs at national level. This could include collaboration with Irrigation and Forestry Departments for sediment studies in existing reservoirs, and follow-up studies on programs initiated in the 1990s under UNCCD.

Water resources planning and information: Evidence-based decision making is currently hindered by both the lack of water-related data and its inaccessibility. The development of a comprehensive data management system would make a significant contribution to evidence based decision making. It is essential that the development of such a water data management system is a government "owned" process.

Potential entry points for LIFT

- Support collaboration between Ministry of Agriculture and Irrigation (MOAI) and Department of Meteorology and Hydrology to collate existing information on surface water availability (river monitoring, dam location and levels etc) and water utilization.
- Support a Dry Zone scoping study to evaluate the potential for establishing an effective water-related monitoring and data management system as a first step in a comprehensive nationwide undertaking, encompassing all relevant government and non-government agencies.
- Work with WRUD, Department of Development Affairs (DDA) and the Department of Geological Survey & Mineral Exploration, Ministry of Mines to
  - Update, finalise and publish the draft maps of hydrogeology of the Dry Zone compiled by Drury (1986)

- Extend work by Min Oo and Thein (2013) in Nyaung-U township, combining Remote Sensing and GIS methods to assess groundwater potential, to the entire Dry Zone
- Commission strategic research on groundwater recharge processes and dynamics for the major aquifers
- Conduct a structured survey of well-drilling companies and individuals to capture informal local knowledge of the location, extent and reliability of groundwater resources
- Collaborate with relevant government agencies in collating a database of groundwater wells, building from data held in local WRUD offices (above)

1 Introduction

This study, on "Sustainable Management of Water to Improve Food Security and Livelihoods in the Dry Zone of Myanmar", was commissioned by LIFT as input to designing its programs for 2013-15.

The Dry Zone of Myanmar is the most water stressed regions of the country and also one of the most food insecure. Of the total population of 10.1 million people in 54 townships of the Dry Zone (MIMU 2013), approximately 43% live in poverty and 40-50% of the rural population is landless (JICA, 2010). The extreme variability of rainfall, high intensities, limited rainfall events in the growing season and poor spatial and temporal variability is believed to be a major constraint to rural livelihoods and hence an underlying contributor to the poverty of many households.

Water related concerns are known to have a strong bearing on food insecurity and low incomes in the Dry Zone, so LIFT commissioned a rapid review of access to and management of water resources as input to the formulation of a LIFT program for the Dry Zone in 2013-15. The aim or the study was to identify priority interventions in the water sector that could improve the livelihoods of rural communities, both smallholders and those without access to land, and that have potential to benefit a significant number of people.

The Dry Zone faces two main challenges in the context of water: reliable supply of safe water for drinking and domestic purposes; and access to water to sustainably increase agricultural production, food security and incomes.

The study aimed to identify:

- key issues with regards to water availability, access and management;
- existing activities being undertaken to address these issues
- priority actions (i.e. targeted interventions) to improve access to and management of water

This is the third of three reports produced from the study, as follows.

- Water Resource Assessment of the Dry Zone of Myanmar (McCartney et al., 2013)
- Community Survey on Water Access, Availability and Management Issues in the Dry Zone of Myanmar (Senaratna Sellamuttu et al., 2013)
- Synthesis of findings and recommendations to LIFT (Report 3 – this report).

This report synthesizes results, analyses existing investment patterns and outcomes, and makes recommendations for priority areas for future investment. Section 2 outlines methods and approaches used. Section 3 summarizes the main agro-ecosystems and livelihood typologies on which the assessment is based, and the main problems and strategies within each zone. Section 4 outlines the potential interventions identified from a range of sources, including a review of existing programs. Section 5 identifies opportunities and priorities for water related interventions, including main factors constraining implementation; knowledge gaps; and potential entry points for LIFT. Section 6 summarizes recommendations for consideration by LIFT.

2 Approach and Methodology

2.1 Conceptual framework

Internationally, there is a very extensive literature on both research and implementation of interventions to improve water management, with a wealth of information on technologies and approaches that have been trialled in different regions and under a range of conditions. Some important insights have emerged from these studies, which provide the conceptual framework for this assessment, summarized as follows:

Technologies are only part of the solution. In many cases, the constraining factor in improving water management is not the technology to be implemented, but how to do it effectively over the long term. Approaches are needed to support implementation through financial mechanisms, capacity building, institutions, business models and technical advice and support (AgWater Solutions 2013; WOCAT 2007).

Agricultural water management (AWM) is more than irrigation. It encompasses a wide range of techniques for retaining, storing and managing water in both irrigated and rainfed systems. Improving the efficiency of water use through soil and water conservation (SWC) measures is also an important component of AWM (CA 2007; WOCAT 2007; AgWater Solutions 2012a).

Storage is more than dams. Water can be stored in a range of ways, forming a continuum from open water in dams and lakes to soil moisture and groundwater, each with different modes of access, costs and environmental implications (McCartney and Smakhtin 2010).

Livelihoods are more than farming, and depend on a broad range of ecosystem services. The use and value of water in supporting ecosystems must be considered in planning and management, within wetlands and rivers but also in the broader landscape (TEEB 2010).

Irrigation is changing. As pumping technologies have become affordable and accessible, there has been a shift away from formal gravity-fed irrigation schemes towards small-scale, individual pumping from both surface and groundwater sources – the "atomisation" of irrigation. Farmer managed pumping provides significant advantages in terms of flexibility, reliability and simple operation and maintenance (Mukherji et al 2010).

Conjunctive use and management of surface and groundwater increase options for water use, and provide better overall control, efficiency in use and productivity (Evans and Evans 2012). **Recharge, retention, and re-use** of shallow groundwater can add substantially to the increment of water available for use. By managing water at landscape scales to maximise retention and recharge, it is possible to extend the chain of water use and reuse within a basin, including ecosystem uses (van Steenbergen and Tuinhof 2010).

Managing water by managing land. Land degradation changes the way water moves through a catchment, increasing the runoff rate and decreasing sub-surface flow and retention in the soil profile. Reversing land degradation is an essential step in improving water productivity, particularly in low-yielding rainfed systems (CA 2010).

2.2 Methodology

This project applied an approach to water investment planning developed under the AgWater Solutions project (awm-solutions.iwmi.org). This approach focuses first on livelihoods, to define the water needs of rural people and the input points where water can make a substantial contribution to reducing risk, improving incomes and food security; then looks for ways to meet those needs, within the constraints of the physical and socio-economic context. The study has five main components:

- A water resources assessment (surface and groundwater) of availability and current use of water resources, and the patterns, trends and variability at different spatial and temporal scales.
- Community survey to evaluate issues of water availability, access and management for different livelihood types in 24 local communities, including analysis of current interventions and how successful they have been in improving livelihoods and food security.
- Evaluation of institutional arrangements in relation to farming strategies and water management practices
- Review of existing studies and programs, to establish the main livelihood patterns, water-related issues, and current investments in water at a regional scale. This included mapping of agro-ecosystems of the Dry Zone using multi-temporal satellite data to distinguish cropping patterns, as an input to spatial delineation of livelihood zones.
- Analysis, synthesis and formulation of recommendations.

Review and consultation

A consultation workshop was held with 40 participants representing key partners and stakeholders in the Dry Zone, including members of the Food Security Working Group (FSWG), government agencies and NGOs (REF to workshop report). This was followed up with individual interviews with groups working in water-related programs in the Dry Zone (Appendix 5).

Field visits to Sagaing and Mandalay Districts were made by IWMI team members in February and March 2013, including consultations with local offices of Water Resources Utilization Department (WRUD) and Department of Irrigation (DI), and inspection of different modes of irrigation in Sagaing, Ye-U, Monywa, Nyaung-U and Sin Te Wa river.

The review drew on a wide range of published literature and reports from previous projects, and the MIMU Who-What-Where database for 2009 to 2012. The past and current interventions reported in our community survey under Component 2 also informed this process.

Water resource assessment

The WRA comprised consultations and a desk study undertaken by IWMI in partnership with the National Engineering and Planning Services (NEPS), a local NGO. Hydro-meteorology and other water-related data were collected from government departments, and supplemented by regional and global datasets (e.g. rainfall data from the Aphrodite database and river flow data from the Global Runoff Data Centre, Google Earth Images and MODIS evaporation data).

Rainfall data from the global Aphrodite database were analysed using statistical methods to characterize spatial variations and temporal trends in the main rainfall features of the Dry Zone.

Available (sparse) data on flows in the Chindwin and Irrawaddy were used to characterize flow variability; and data on infrastructure compiled to estimate water storage in large and small reservoirs. A map of irrigated areas was derived using simple visual inspection of Google Earth images from Nov 2011 – April 2012; and compared with estimates of irrigated areas from other sources (MOAI, FAO and JICA). Irrigation water requirements in the Dry Zone were estimated using MODIS 16 evapotranspiration data for 3 locations in the north, central and south of the Dry Zone.

Hydrogeological data and information on groundwater use and recharge as well as water quality were compiled, as the basis for an assessment of groundwater potential and sustainability at regional scale.

Community Survey

A community level survey of 24 villages in the Dry Zone was conducted to ascertain local water availability for different uses and opportunities and constraints to access and manage water as perceived by local people. Four villages in each of six townships were selected, based on a combination of factors including irrigable area, location (as a proxy for agro-climate), the presence or absence of existing LIFT projects, rainfall shocks ("stressed" versus "non-stressed" villages) and irrigation source. Three focus group discussions (FDGs) were conducted in each village, with 8-10 participants in each group, as follows:

- FGD 1: with community leaders on general background and water resources in the village
- FGD 2: with marginal farmers on water access, availability and management
- FGD 3: with landless farmers on water access, availability and management.

In addition, a short questionnaire on groundwater to derive a general understanding of the nature of groundwater irrigation technologies and associated socio-economic factors was administered to a small purposive sample of seven well owners (six owned tube wells and one owned a dug well). Case studies of groundwater use in different context were described in detail; and the socio-economic impacts of adopting groundwater irrigation were analysed based on a survey of 7 farmers in different areas.

Institutional analysis

Institutional analysis is derived from an in-depth case study analysis using a purposive sample including three villages in Sagaing township with different levels of access to water (Ta Ein Tel, De Pa Yin Kwal, and Taung Yin). Focus group discussions and key information interviews were conducted in each of the three villages. In addition, 11 key informant interviews were conducted in townships in Sagaing (Sagaing, Taze), Mandalay (Nyaung-U, KyaukPaDaung), and two townships in Magwe region (Minbu, Taungdwingyi), with staff from the Water Resources Utilization Department (WRUD), Irrigation Department, Myanmar Agricultural Service (MAS), and Network Activity Group (NAG). Data gathered during the field research were complemented with literature review.

3 Water and livelihoods in the Dry Zone

3.1 Agro-ecosystems of the Dry Zone

Although the Dry Zone is often considered a relatively homogeneous region of low rainfall and limited topographic relief, it hosts diverse agro-ecologies, farming systems and socio-economic conditions. The farming systems of the Dry Zone are a complex mixture of paddy cultivation, non-rice crops (pulses, oilseeds, vegetable and others) and large and small livestock. Traditionally in Myanmar, land is described in terms of suitability for different types of cultivation (see Box 1), with the main distinction between *le* (paddy) and *ya* (dryland). Dry Zone systems on all land types are characterised by a variety of forms of mixed cropping, intercropping, relay and phased plantings and rotations using a wide range of crops, representing skilful adaptation to low rainfall conditions (Kahan 1999). Cropping under rainfed conditions in the Dry Zone is high risk, and access to water for irrigation is a major determinant of the options available to farmers, to secure the wet season crop and allow reliable cultivation of a second crop.

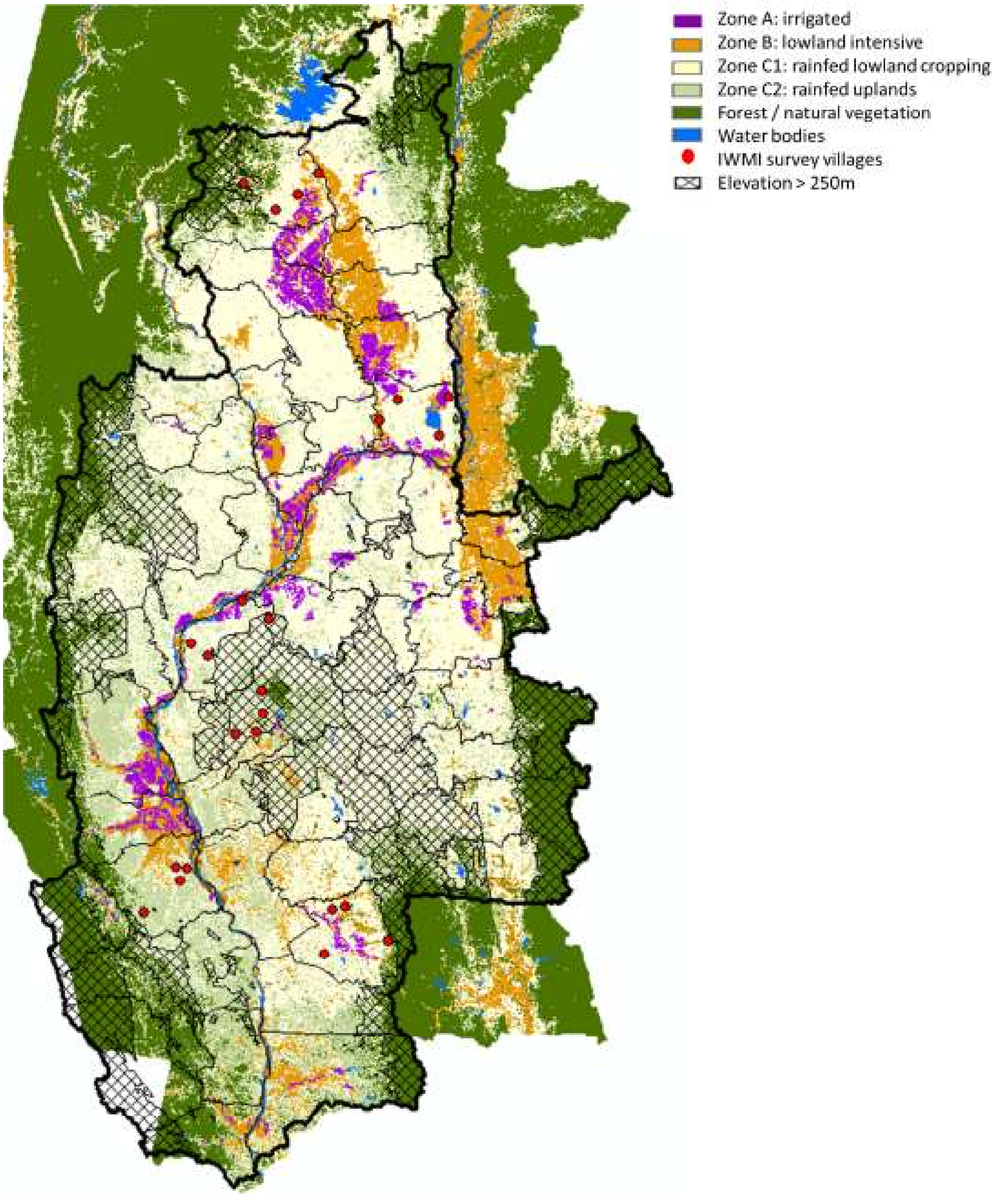
Previous studies have emphasized the importance of recognizing and working with this diversity in formulating development programs (Cools 1995, Kahan 1999, JICA 2010). To describe this variability, and to provide a basis for extrapolating results from the village survey, we defined agro-ecosystems, as follows:

- A: intensively farmed croplands (*le*) with access to irrigation in all seasons
- B: croplands with access to supplementary irrigation (includes *le* and *kaing-kyung* lands)
- C: rainfed areas (*ya* lands)- mixed cropping and grazing
    - C1 – rainfed lowland cropping
    - C2 –rainfed uplands (mixed grazing and cropping)

This definition draws on typologies described in previous studies (JICA 2010; Kahan 1999), and also reflects the sampling frame used in the village survey in Report 2.

Delineating these agro-ecologies spatially is not simple, as they form a complex mosaic depending on soil type, topography and access to water and all may occur within the territory of a single village. However, in broad terms, areas can be delineated where specific agro-ecologies dominate. We propose delineation of agro-ecosystems on the basis of cropping patterns determined from MODIS imagery, based on the length and intensity of seasonal greening – Figure 3.1. Appendix 2 sets out details of the methods used in deriving the map. **Note that the agro-ecosystems map should be considered an exploratory product, which requires validation.**

Figure 3.1 Agro-ecosystems of Dry Zone



BOX 1

Traditional land types in the Dry Zone of Myanmar

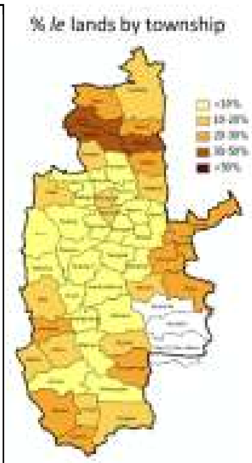
***Le* (paddy land)**: flat land suitable for paddy cultivation, often with impermeable heavy soils. Level terraces on hill slopes for paddy are also classified as *le*. Paddy is grown in the wet season, and a second crop of either rice of other crops (oilseeds, pulses), depending on availability of water.

***Ya* (dry land)** : crop land not suitable for paddy cultivation. In the rainy season, groundnut, sesame, sunflower and pulses are grown.

***Kaing-Kyung* (alluvial/island)** : land near rivers, flooded during the rainy season, including areas within the river bed. Soils are generally fine sandy loams or loamy sands, and very fertile. Cropped in the dry season.

***Taung-Ya* (shifting cultivation)** : land in hilly areas under shifting cultivation. Crops are grown only in the rainy season. Upland rice is a major crop but maize, sesame, soybean and vegetables are also grown.

(JICA 2010)



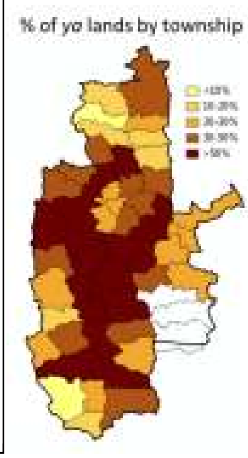
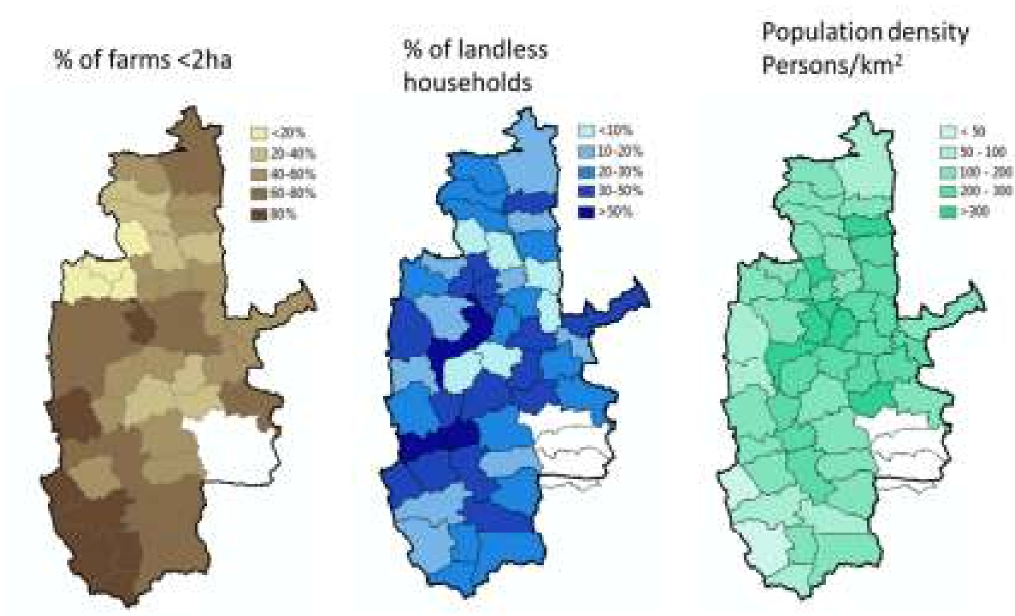


Figure 3.2 Land ownership and population in the Dry Zone, by township; taken from JICA 2010.



3.2 Water-related issues by agro-ecosystem

Zone A: Intensive lowland cropping with access to dry season irrigation

Extent and location: Irrigated areas**,** with access to water all year (for summer, monsoon and winter crops), are found mainly within formal irrigation schemes, including major schemes in Minbu, Kyauske and Ye-U / Shewbo; and a number of smaller schemes, particularly pumped irrigation systems long the Irrawaddy and Chindwin Rivers. Irrigation is usually developed on *le* lands, with higher agricultural potential, though some schemes report problems with sandy soils. Estimates for the extent of irrigated area vary (see Table A4.1 in Appendix 4): IWMI mapping of 0.267 m ha, specifically for the year 2011/12 represents a lower bound. JICA (2010) estimated total Dry Zone irrigated area at 0.38m ha (5% of total area and 12% of cultivated land).

Livelihood options: Cultivation of monsoon paddy is almost always an activity for landed farmers. This is usually followed by two post monsoon crops (sesame, green gram, cotton, groundnut, green pea). Marginal farmers usually grow a pre-monsoon crop (groundnut, gram, pigeon peas), followed by a monsoon crop (sesame or rice). Marginal farmers mostly keep cattle, goats and poultry; while for the landless, poultry and pigs are important livelihood options.

Issues with water sources: Formal dry season surface irrigation has high operation and maintenance costs, which are often unrecovered by WRUD due to subsidized water fees. Thus these systems are not regularly maintained. Canals, apart from the main lines, tend to be unlined, leading to high water losses. Due to shortage of electricity, water can often not be pumped at the appropriate time in pumped systems. Sediment loads in rivers can also adversely affect irrigation performance and costs. Thus farmers often have to deal with gaps in irrigation schedule, with farmers at the tail end often not getting enough water. The water source for livestock and domestic use is mostly the same: private manual wells are used by landed, marginal and landless farmers. River water is an important source for marginal and landless farmers. Wells are more secure options, while river water can be harder to access in the dry season.

Coping strategies: Landed farmers may use groundwater through motorized and manual tube wells to supplement water from formal irrigation interventions, or during unexpected dry spells. Marginal farmers are unable to do so, since they are not as well off to afford private solutions. Landed and marginal farmers also resort to pawning or selling assets such as land, jewellery and livestock to tide them over reduced yields either due to dry spells in the monsoon season, or due to droughts in the dry season. Landless farmers are also more likely to reduce consumption during dry spells. Pawning and selling assets is also done to cope with floods. With respect to livestock, goats, pigs and poultry are often preferred over cattle, which is more suited to the environment. Landed farmers tend to be relatively less water-insecure. Marginal farmers may rely on dug wells to water livestock when regular sources are stressed. Landless farmers often rely on the patronage of landed farmers in the village, who may share their water sources during stressed times.

Survey villages in zone A:
Mandalay: Nwar Kyoe Aing, Ohn Hne Chaung
Sagaing: De Pa Yin Kwal; Ta Ein Tel; Sarr Taung

Zone B: lowlands (*le*) with access to supplemental irrigation

Location and extent: supplemental irrigation is usually developed on lands with higher agricultural potential (*le* lands). Sources of water for supplemental irrigation are diverse and can include more than one source per village: an irrigation scheme functioning only in the monsoon season; groundwater; or a rainwater storage pond. Irrigation is mostly used to grow a second crop at the beginning or end of the monsoon, or to limit the impact of dry spells or drought on the main crop; summer cropping is limited. Based on agro-ecosystem mapping, we estimate that supplemental irrigation may be used on around 9% of total land area (0.73 m ha), including *kaing-kyung* lands, with the highest occurrence in Shewbo, Kyaukse and Thayet districts.

Livelihood options: monsoon paddy is common, but other crops may be grown, including sesame, green pea or green gram in the monsoon, followed by a post monsoon crop of groundnut, chickpeas, or pigeon peas. Marginal farmers grow a monsoon crop of pigeon peas, groundnut, rice or sesame,. Poultry and goats are more important assets than cattle for both marginal and landless farmers, with pigs forming an important option for the landless.

Issues with water sources: Landed and marginal farmers mostly use tube wells with pumps for irrigation. Electric pumps, while more reliable, have higher fixed costs as they are expensive. While electricity is subsidized, it is in short supply. Diesel pumps have lower fixed costs, but the price of diesel is rising, making the variable costs high. Not much is known about the quality of groundwater in Myanmar; this lack of information increases the risk of choosing an inappropriate site to install a tube well. Shallow tube wells are cheaper to dig than deeper ones, but are also more likely to suffer from water quality issues. Unconstrained pumping may lead to depletion of the groundwater resource. The water source for livestock and domestic use is mostly the same, with private manual wells used by landed, marginal and landless farmers.

Coping strategies: Farmers tend to rely on cropping patterns as a coping strategy, often not growing rice, and instead choosing to grow sesame during the monsoons. They may buy water from landed farmers with private wells during severe dry spells in the rainy season, depending on the stage of cultivation at which they crop is. As in areas with dry season irrigation, landed and marginal farmers also resort to pawning or selling assets such as land, jewellery and livestock to tide them over reduced yields either due to dry spells in the monsoon season, or due to droughts in the dry season. Landless farmers are also more likely to reduce consumption during dry spells. Pawning and selling assets is also done to cope with floods. With respect to livestock, landed farmers tend to be relatively secure, with farmers using irrigation water for watering livestock during severed dry spells. Marginal and landless farmers may rely on the patronage of landed farmers in the village, who may share their water sources during stressed times.

Survey villages in zone B:
Magwe: Yae Twin Kone, Kone Thar, Kyauk Tan; Ma Hti San Pya, Tha Phan Kone
Sagaing: Daung Gyi, Kan Du Ma, Pa Kar

Zone C1: Rainfed lowland croplands

Location and extent: Rainfed croplands constitutes the major part of the Dry Zone (from the agro-ecosystem mapping, around 50% of total land area). Conditions vary in terms of soils, topography and rainfall: rainfall in the central dry zone is both lower and less reliable than in the townships around the periphery (see Report 1).

Livelihood options: Landed and marginal farmers may grow two crops a year, often practicing mixed cropping. The most common crops consist of groundnut (pre-monsoon to monsoon; monsoon to post monsoon); green gram (post monsoon), pigeon peas (pre-monsoon to post monsoon), sesame (monsoon), beans (winter) and sunflower (monsoon). Poultry and goats are more important assets than cattle for both marginal and landless farmers, with pigs forming an important option for the landless.

Issues with water sources: Untimely or inadequate amount of rainfall leaves farmers particularly vulnerable to the vagaries of the weather, with landed and marginal farmers experiencing low crop yields. Public wells and ponds are the most important source of water for livestock and domestic use. During dry spells, ponds may dry up, putting more pressure on groundwater, and leave the landless especially vulnerable.

Coping strategy: Cropping patterns tend to be more diverse, with farmers often preferring to grow pulses and oilseeds in mixed cropping. During severe dry spells, marginal and landless farmers may take their children out of school to supervise livestock, while they find casual work to supplement household incomes. Landed and marginal farmers also resort to pawning or selling assets such as land, jewellery and livestock to tide them over reduced yields either due to dry spells in the monsoon season, or due to droughts in the dry season. Landless farmers are also more likely to reduce consumption during dry spells. Pawning and selling assets are also done to cope with floods. In comparison to areas with dry season and supplemental irrigation, farmers in rainfed areas are the worst hit during seasons of water scarcity. They may have to buy water from farmers in other villages, and transport barrels of water on bullock cart. The landless are worst hit; often not owning a bullock cart, the costs of procuring water during stressed times are the highest for this sub-category.

Survey villages in zone C1:
Mandalay: In Taw, Chaung Phyar
Magwe: Let Tet, Taik Pwe
Sagaing: Bay Yin

Zone C2: rainfed uplands

Location and extent: a mosaic of shrublands used for grazing and small areas of dryland crops, mostly on sloping lands. This system comprises some of the poorest areas in the Dry Zone and is concentrated in, but not restricted to, the topographic uplands (shown in Figure 3.1 as the cross-hatched area, with elevation above 250m). This pattern is typical of the uplands of the Bago Hills, a range of low sandstone hills with sandy soils of generally low agricultural productivity, and low rainfall.

Livelihood patterns: The proportion of cultivated land is low; and grazing of livestock (mainly goats) is an important component of livelihoods. Rainfed cropping of includes groundnuts, pulses and oilseeds, cotton and small areas of upland rice. Yields in lands of poor quality (sloping, eroded or with gravelly soils) may be half or less than flat lands in the same area (Cools 1995), and larger farms are needed to make a sustainable living. Previously, shifting cultivation was common in some areas, particularly in southern and western Magwe division, but over the last 20 years much of this has converted to permanent cultivation.

Issues with water sources: poor soils and sloping lands mean farmers are very vulnerable to low and variable rainfall. In these areas, total crop failure is common in years of low rainfall. During the dry season, public wells and ponds / small dams are the most important source of water for livestock and domestic use. Soils are generally poor and sandy; identifying suitable sites for surface storages can be difficult and widespread erosion in sloping lands results in sedimentation of dams.

Coping strategies: Livelihood options are limited in these areas, and poverty is widespread. Larger farms are needed to make a sustainable living. In bad years, both farm-households and landless households may need to borrow from neighbouring villages or towns. Adapting crop patterns to seasonal conditions is an important strategy for dry years. Soil and water conservation (SWC) methods (bunds, strip cropping, agroforestry) are known but often sacrificed to the pressures of producing a crop. Other coping strategies are similar to those in the rainfed cropping areas (above).

Survey villages in zone C2:
Mandalay: Kan Ma, Thea Pyin Taw, Kyauk Sit Kan, Pha Yar Gyi Kone
Magwe: Kha Yu Kan
Sagaing: Taung Yinn

3.3 Groundwater and livelihoods

Although groundwater is increasingly important for irrigation in the Dry Zone, little is currently known about the ways that it is used, and the significance for livelihoods. For this reason, particular focus was placed on understanding groundwater use during field visits and in the village survey, which included structured interviews with seven farmers using groundwater, to explore the opportunities and constraints.

Smallholder farmers across the Dry Zone access groundwater in diverse ways, involving different types of wells, methods for lifting water, scale of operation, depth of groundwater, source of funds, types of institutions, and degree of operational risk. Our study tour to the Dry Zone in late February 2013 identified 4 main types, presented in Table 3.1. The 7 farmers interviewed were all type 2 irrigators.

Type 1 represents the largest-scale 'formal' schemes that are implemented by the Water Resources Utilization Department (WRUD), usually with international donor financing or support. Examples are the Monywa Groundwater Irrigation Project in of Monywa District, Sagaing Division and the 99-Pond Yinmarbin Artesian Zone Project in Yinmarbin Township, Sagaing Division. Other WRUD projects are believed to be under construction. Type 1 projects typically draw water from deep tube wells and rely on dedicated multi-phase power supply for large electric pumps (except where naturally 'free-flowing' artesian conditions prevail, as at Yinmarbin) and support command areas fed by lined and unlined distribution network of canals.

Type 2 systems access groundwater from shallow dug wells or tube wells that are typically less than 30 m deep and require much lower upfront and on going capital investments than type 1. Most are financed and managed by the farmers themselves, individually or in small groups (see BOX 2). Lifting is performed by small-scale motorized pumps (<12 HP) that operate effectively where the water level in the well table is within about 6-8 m of the ground surface. Production systems do not differ substantially from those of the larger scale systems and usually involve irrigation of small areas of a few acres for high-value crops such as vegetables to support local markets or export of high valued produce to regional markets such as the neighbouring states in China (see BOX 2).

Type 3 is opportunistic. During the dry season water is drawn from the open pools present in irrigation canals via small motorized pumps. These pools reflect the local groundwater table, and are sourced mainly from infiltrated canal water and subsurface return flows from nearby fields. In the wet season the same infrastructure is used to draw surface water from the canals.

Type 4 systems are established on alluvial river beds (*kaing-kyung* lands) when water levels recede during the pre-monsoon season. Rudimentary wells or pits are constructed and extraction methods like ropes and buckets, or human or animal-operated mechanical pumps, or occasionally treadle or motorized pumps are used. Being seasonal in nature the wells must be rebuilt yearly, and can be at high risk in a floodplain setting where heavy losses may be incurred by storms or early breaks to the season.

Small scale irrigation by pumping from groundwater characteristic of types 2-4 do not require costly infrastructure and gives farmer direct control over water access which may be lacking in centralized irrigation systems.

Five case studies are described in detail in Appendix 3, as follows

- Monywa Groundwater Irrigation Project (Type 1)
- Tail-end farmers at Monywa (Type 2)
- Water Trading and Co-investment at Nyaungkhan Village (Type 2)
- New private well owner at Tanpinkan Village, Taungtha Township (Type 2)
- Recession farming Sin Te Wa River (Type 4)

The results of the village survey on groundwater are presented in Report 2.

The case studies and survey confirm that groundwater can be an important means for farmers to improve their livelihoods, particularly during the dry season when alternative livelihood options are limited. The best returns come from cultivation of high value crops. Job opportunities for landless workers in irrigation management emerge in around 70% of cases. Assured access to water for domestic and livestock use is an indirect benefit.

The total investment costs needed to establish groundwater irrigation are highly conditional upon the local conditions and can vary by an order of magnitude. Knowledge of the hydrogeological conditions can reduce costs and minimize poor investments. Under optimal conditions, the payback times on initial investments can be very short, but on average were around 3-5 years. For most well owners, the main constraints to use of groundwater are the high cost of fuel and to a lesser extent the maintenance-related costs in operating motorized pumps. The high upfront cost of setup, though not accounted for in the survey, is also likely to be a barrier.

Table 3.1 Modes of groundwater development for irrigated agriculture in the Dry Zone

1. Deep tube wells[1]	2. Shallow tube wells and dug wells - permanent	3. Indirect pumping	4. Shallow infrastructure
• Formal irrigation • Larger-scale • Donor or government funding • Large electric pumps[2] • Collective-driven • Market-oriented • Highly subsidized, • Low risk	• Informal • Small-scale • Private of NGO funding • Farmer-driven • Unsubsidized • Low risk	• Informal • Small-scale • Private funding • Farmer-driven • Manual lifting • Unsubsidized • Opportunistic • High risk	• Informal, • Small-scale • Private funding • Farmer-driven • Seasonal • Unsubsidized • Opportunistic • Moderate risk

[1] somewhat arbitrarily, the deep wells are typically drilled wells are >30 m depth
[2] except for artesian subsurface conditions

BOX 2

New private well owner at Tanpinkan Village, Taungtha Township (Type 2)

Mr Shwe Myaing constructed a new well four months before our visit, after years of working with rainfed agriculture. He recently received a family inheritance, which he invested in improving the water management of his farm. A deep well was needed, because of the upland location of his farm, with a large diameter well to 6m and tube well to 55 m. The top few meters of the well are in limestone, but the most productive layer is the 'brown sands' found at depth. The total cost was 1.1 M kyat: 300,000 kyat for mechanical drilling of the well; 350,000 kyat for the down-hole pump; and 350,000 kyat for a large diesel engine, purchased second hand.

The well irrigates a field of 0.5 ha (Figure A3.5). For the first irrigated crop, onions were planted; when we visited, the crop was 1 month old. Land preparation took 1 month and cost 100,000 kyat. The soils are calcareous sands with low fertility, so cow dung and urea were applied. The expected yield from this harvest is 3000 Viss (4890kg). The selling price at present is 300-400 kyat per Viss.

Mr Shwe Myaing previously produced sesame and some mung beans under rainfed conditions; when the rains were good he was able to harvest 10 baskets (about 370kg) at most, but often the crop failed. Access to irrigation means that it would be possible to produce watermelon for export to China, with much higher potential returns. However, he chose to plant onions, like many other farmers in the area, citing lack of experience and high risk as the main constraints.

The newly constructed deep well pumping water that is manually spread across the first crop of onions

4. Identifying interventions

A broad suite of water-related interventions is already used within Dry Zone. Existing studies and agencies working in the area emphasize that there is good understanding of issues and potential solutions within local communities and agencies. The need is not so much for new technologies, but for approaches to support implementation; and refinement and targeting of known technologies. Existing and potential interventions for water management in the Dry Zone were identified, based on:

- Existing programs and investments (Section 4.1)
- Analysis of livelihood patterns and consultation with communities (Report 2)
- Physical context and constraints (Report 1)
- International experience in similar terrains (below Section 4.4)

4.1 Current and past programs and investments – patterns and outcomes

Over the last 20 years, considerable effort has gone into provision of water for rural communities in Myanmar, with most programs targeting either domestic water supply; or agricultural water / irrigation. A review of past programs was conducted, based on the initial IWMI Workshop, interviews with groups working in water-related programs in the Dry Zone, the MIMU Who-What-Where database; and review of the literature. Details are provided in Appendix 4, and a summary of the types of interventions currently in use by different agencies and NGOs in the Dry Zone is given in Table 4.1.

The past and current interventions reported in our community survey under Component 2 also helped inform this process; these are described in detail in Appendix 1 of Report 2.

Domestic and community water supply

Provision of safe water for communities is an important priority for both the Government of Myanmar and international donors and NGOs. IHLCA survey 2009-2010 indicated that the Dry Zone has made significant improvements since 2005, so that only Magwe lags behind the national average of 69.4% (Table 4.2). Nationally almost two-thirds of the rural population draw drinking water from wells (MNPED/MH 2010).

Programs for rural domestic water supply have been conducted by a number of government agencies (Department of Development Affairs (DDA); Ministry of Health; and the Water Resource Utilization Department (WRUD)), often in collaboration with UN agencies (including UNICEF, UNDP, UN-Habitat and WHO), which have worked with the government on provision of water and sanitation in the Dry Zone since the 1970s. UNDP is currently supporting provision of water supplies to over 1700 villages in the Dry Zone, under the UNDP Human Development Initiative Integrated Community Development Program and the UN Human Settlements Program "Shae Tot" (MIMU WWW database, Nov 2012). Non-government organisations, both local and international, are active in the water supply sector. MIMU WWW database lists 12 organisations (excluding UN agencies) active in the areas of safe water supply and construction and rehabilitation of water facilities in the Dry Zone in 2012, working in more than 465 villages.

Table 4.1 Water-related interventions currently in use or under consideration in programs in the Dry Zone. Where no agency is given, the technology or approach was discussed in general terms in meetings or consultations, without a reference to a specific program.

Purpose	Technology / approach	Agency
Water supply – irrigation schemes	Spate irrigation	WRUD
	Gravity-fed irrigation schemes	DI
	Pump irrigation schemes	WRUD
	River diversion	
	Canal irrigation	
	Irrigation system improvement	Action Aid
	Optimising reservoir operations	
	Sluice gates	CDN
Water supply - groundwater	Tube wells (deep)	Action Aid
	Artesian wells	Action Aid
	Tube wells (shallow)	ADRA
	Groundwater recharge	ADRA
	Storage tank with deep well	
	Wells (hand dug)	Action Aid
Drainage	Dike/Road	Action Aid
	Drainage improvement.	
	Culvert	
Irrigation-water application	Drip irrigation kits	Proximity
	Micro-gardens, hydroponic greenhouses	
	Hydroponics / drip irrigation / RWH	TDH
Surface storage	Dams / ponds	
	Household water container	
	Sand dyke /sand dam	Action Aid
	Turkey nest dams (pumped from rivers)	
	Dams and weirs	Action Aid
	Rainwater tanks from roof (schools)	ADRA
	Mini Earth Dam (with government machines)	Action Aid
	Pond fencing	
	Pond renovation.	Action Aid
Water lifting technologies	Hand pumps	
	Small pumps	
	Solar pumping from tube wells	
	Treadle pumps	Proximity
Water access	Piped water supply by gravity flow (PSGF)	
	Household water container	
	Water fetching points (i.e. decreasing work in accessing water)	

Watershed management	Reclaiming degraded land	CDN
	Removal of thorn bushes	
	Re-vegetation	
	Erosion control	WHH
	Removal of sand from canals	WHH
	Bank stabilization in rivers	WHH
	Soil water conservation (mulching etc)	
	Community forestry	Action Aid
	Woody weed removal	ADRA
	Reforming cultivable land (levelling, adding topsoil)	
	Community forestry	
Implementation approaches	Women Leadership – advisory mother groups	Action Aid
	Youth (Fellows) leadership	Action Aid
	Community Action plan(Approach)	Action Aid
	Collaboration with local government	Action Aid
	Cash for work – as livelihood improvement as well as labour	ADRA
	Integration of water supply into livelihoods	ADRA
	Community participation	ADRA
	Training	ADRA
	Sustainable agricultural techniques tailored to local environment	TDH
	Farmer field schools, technical assistance	TDH, CDN
	Market value chains	

Table 4.2 Access to safe drinking water (IHCLA 2010)

	2010					2005
% of population	Poor	Non-poor	Urban	Rural	Total	Total
Magwe	64.4	61.9	85.3	60.2	62.6	56.8
Mandalay	67.7	79.4	88.2	71.5	76.3	75.5
Sagaing	64.9	74.2	78.6	71.8	72.8	59.9
Myanmar	**62.2**	**71.9**	**81.4**	**65.2**	**69.4**	**62.6**

While recent progress has been impressive, the fact remains that more than 1 in 4 people in the Dry Zone do not have access to a secure source of safe water. A critical lesson from current programs is the importance of embedding water into broader village livelihood strategies, taking account of the full range of uses, rather than a focus on domestic supply separate to other needs. ActionAid and ADRA have developed participatory methods for working with communities to ensure that water interventions are closely linked into village development plans, with clear delineation of responsibilities for construction, operation and maintenance. They also stress the importance of improving access to water (as well as availability) through piped systems, access points and pumping for ponds (Proximity, ActionAid).

Tube wells and small reservoirs are the most common focus for current projects on domestic water supply; but for both, on-going maintenance is a significant problem. JICA (2010) found that many existing rural water supply tube wells were in poor repair or not functioning. They attribute this in part to poor siting and construction, and in part to lack of trained engineers for operation and maintenance. Maintenance and desilting of ponds at least every 2-3 years is critical to maintain viable volume; but NGOs working in the Dry Zone report that regular maintenance is often neglected, which means that more expensive and difficult renovation is then needed.

Water for agriculture

The Government of Myanmar has prioritized irrigation since the 1980s, with a major program of construction and irrigation development. In 2000, the government set a national target to make irrigation available for 25% of agricultural land, with an emphasis on provision of irrigation for summer paddy (Khon Ra 2011). Estimates of total irrigated area in the Dry Zone (and nationally) vary very widely: see Report 1 and Appendix 4). Schemes are mainly gravity-fed canal systems from storage in dams or weirs; or pumped irrigation projects (PIP) drawing on rivers. There are smaller areas of groundwater irrigation, spate irrigation and small-scale water harvesting. Groundwater irrigation is only 5% of total area, but is growing at almost twice the rate of other types (Report 1). Most large irrigation schemes have been funded by the government, with some support from FAO. In general, agricultural water supply is approached by NGOs and donors as a component of broadly based livelihood programs e.g. HDI-IV Integrated Community Development Project (ICDP) and CSEVI Shae Thot programs.

The performance of formal irrigation schemes has been sub-optimal. The actual area irrigated is much lower than nominal command area. 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, operation and maintenance issues, availability of power for pumping, and inappropriate siting and soils (LIFT 2012, 2011). Many systems were designed to grow rice under flood conditions, and are insufficiently flexible for other crops; and 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 O&M.

Watershed management / land and water degradation

The main causes of land degradation in the Dry Zone include deforestation (due to agricultural expansion, commercial and illicit logging, and excessive cutting for charcoal and fuel wood), poor agricultural practices, overgrazing, and shifting cultivation, all of which are exacerbated by demographic pressures. Myanmar has one of the highest rates of deforestation in the world (BEWG 2011). Dry forests around the periphery of the Dry Zone are particularly under threat from agricultural encroachment and intensification of shifting cultivation (Leimgruber et al 2005; NFI 2007).

Watershed management programs in the Dry Zone have been initiated in three different contexts:

- Soil and water conservation programs at field scales to prevent erosion and loss of top soil, with related declines in soil fertility, water-holding capacity and crop yields (e.g. Kahan 1997)
- Community forestry, soil conservation and tree planting projects in small catchments to protect village water supply dams and ponds from siltation and improve water quality; with related initiatives in fuelwood substitution and biogas
- Large scale catchment reforestation programs to protect infrastructure from impacts of sedimentation (in 2002, the Forestry Department began implementation of a Watershed Management Plan to protect and rehabilitate 2 million ha in the catchment areas of 52 newly constructed dams).

The UN has been active in watershed management programs, through the UNDP HDI program (on going); and the FAO programs on agricultural development and environmental management in the Dry Zone during the 1990s (Cools 1995; Carucci 1999). The National Commission for Environmental Affairs (NCEA) in 2002 compiled a National Action Plan to Combat Desertification under the UNCCD (NCEA 2005).

Despite some major programs in watershed management, and a proposed DGDry Zone integrated plan for 30 years 2001-2031 covering forest conservation and land management, it is not clear if the programs have been effectively implemented, or if that there has been a significant change in rates of degradation. Cools (1995) demonstrated positive economic returns from SWC measures in the Dry Zone at farm level; but noted that as farm sizes have decreased, low incomes and lack of savings have meant that for many farmers are unwilling to sacrifice land or invest income in SWC. A review of Community Forest Programs in Myanmar found that their performance was adequate but sub-optimal in terms of both forest regeneration and improving livelihoods; and that sustainability, particularly in the case studies in Mandalay Region, was problematic (Kway Tint et al 2011). WHH (Karin Luke) report that in upland areas of Pauk, degradation is at critical levels, with widespread gullying, loss of topsoil and changes in river morphology due to large volumes of sand, which also clog irrigation canals, making them unusable. She concluded that community forest conservation and agroforestry projects had had a measure of success, but these are at small scale, and there is an urgent need to scale up to regional or national level, since degradation is beyond the level where it can be tackled by small projects.

4.2 Community needs and preferences

The IWMI village survey examined existing water management interventions at village level, and perceptions of their effectiveness. In addition, villagers were asked to identify potential interventions that were of priority to the local communities. Potential interventions were elicited from all focus group discussions during village surveys. After discussion and explanation of the intervention, participants voted anonymously for preferred approaches. This process and outcomes are described in detail in Report 2. Results are summarised in Table 4.3.

Rehabilitation or construction of a rainwater-harvesting pond is a preferred investment in almost all areas, especially in rainfed and dry-season irrigation areas, by all farmer types. FGDs with villages indicate that the villages themselves can supply the labour and mechanical resources required for such investments. Rehabilitation or extension of existing irrigation infrastructure is a preferred option among landed and marginal farmers in villages with wet season irrigation. In contrast, groundwater interventions are preferred over others by landed and marginal farmers in villages with supplemental wet season irrigation.

Table 4.3 Farmer preferences for potential water-related interventions (from Senaratna Sellamuttu et al 2013)

Farmer type	Landed			Marginal			Landless		
Access to Irrigation / Proposed intervention	Rainfed	Wet season	Dry season	Rainfed	Wet season	Dry season	Rainfed	Wet season	Dry season
Rehabilitation and extension of irrigation infrastructure	0.06	0.12	0.50	0.07	0.18	0.28	0.05	0.09	0.28
Collective well for irrigation including electric pumping station	0.04	0.19	0.07	0.07	0.12	0.07	0.05	0.13	0.04
Collective rainwater harvesting pond rehabilitation or new	0.29	0.09	0.24	0.30	0.14	0.31	0.34	0.17	0.46
Collective groundwater for domestic use and livestock	0.10	0.02	0.00	0.11	0.00	0.05	0.08	0.08	0.09
Sand dam/embankment for water storage	0.10	0.00	0.00	0.18	0.01	0.01	0.10	0.01	0.01
Watershed management program	0.01	0.01	0.10	0.01	0.02	0.02	0.02	0.05	0.03
Embankment protection against flood	0.02	0.07	0.02	0.03	0.11	0.02	0.02	0.05	0.02
Rainwater harvesting tank for domestic use and garden watering	0.10	0.03	0.02	0.08	0.02	0.05	0.08	0.06	0.07
Tube well or Dug well (+diesel pump) for irrigation purpose	0.13	0.36	0.05	0.07	0.19	0.18	0.13	0.18	0.03
Other	0.13	0.12	0.00	0.09	0.19	0.00	0.13	0.18	0.00

4.3 Physical constraints and limits to WR development (from Report 1)

A water resource assessment was conducted to provide information on the physical constraints and limits to water resource development, and describe the context in which decisions about water resources are made (Report 1).

The study confirmed that both relatively low rainfall and rainfall variability are key constraints to rainfed farming, particularly in the centre of the Dry Zone. Seasonal scarcity is the key factor limiting many peoples' access to water for domestic uses during the dry season. Lack of predictability both in the amount and timing of rainfall makes rain-fed farming extremely high risk. During the wet season flooding is frequently a problem in many places. A significant reduction in rainfall amounts in June in recent years, combined with the very high variability in the onset date of the wet season, is increasing the risk of drought at the beginning of the rainfed crop cycle. This vulnerability is particularly high in the central part of the Dry Zone.

The study also confirmed high seasonal and inter-annual variability in river flows. There is considerable uncertainty in the area actually irrigated, with very different estimates from different studies. Current irrigation is mainly supplementary to extend the wet season growing period or protect wet season crops, rather than full dry season irrigation. Actual volumes used in irrigation are quite small compared to runoff, and with respect to water, expansion of irrigation is possible. Currently availability of surface water (from rivers and storage) is less limiting than access, due to costs of pumping, and sparse infrastructure in areas remote from the major rivers. The extent of large (river) and small (local) storage developed within different districts varies very significantly. Local storage as a proportion of total runoff is significant only in Meiktila and Myingyan; while large reservoirs have been built on tributaries of the Irrawaddy in Shwebo, Minbu and Kyaukse. Insufficient storage capacity and irrigation infrastructure in appropriate locations, as well as poor management of the existing infrastructure, means that both farmers and the landless are exposed to climatic variability, with all the associated risks that entails.

Review of existing hydrogeological data suggests that groundwater constitutes only a moderate resource, which is already quite heavily used. Estimated withdrawals at district level, as a percentage of annual recharge, range from 5-55%, but are mostly around 20-30%. It is estimated that groundwater recharge is sufficient to irrigate an additional 110,000 to 330,000 ha of land, with the highest potential (in terms of water availability) in Monywa, Shwebo and Pakokku. However, water quality (salinity and arsenic) is an issue in some places.

On the basis of this analysis, the following interventions were identified.

- A strategic approach to water resource planning, including
  - Development strategy for future investment in water resources
  - Groundwater Assessment
- Improved water-related data management
- Small-scale water harvesting and storage for supplementary irrigation
- Soil and water conservation at particular locations to enhance infiltration and water retention in the soil profile to stabilize and increase crop yields
- Groundwater development conjunctively with surface water (e.g. where appropriate for tail-enders within formal irrigation schemes)

4.4 International programs on AWM

A number of major international programs have been completed over the last 5 years focusing on agricultural water management (AWM). These have documented an extensive set of case studies and examples of AWM interventions in different contexts, which form a valuable resource for exploring options for water management:

- AgWater Solutions project (http://awm-solutions.iwmi.org/) including a database of over 150 case studies http://agwaterdb.iwmi.org/login.php
- 3R (Recharge, Retention and Reuse) project http://www.bebuffered.com/
- World Overview of Conservation Approaches and Technologies (https://www.wocat.net/), including a database of >500 case studies (encompassing soil and water management)
- Improved Management of Agricultural Water in Eastern and Southern Africa http://imawesa.info/

Table 4.4 describes the types of interventions that may be relevant at different scale and for different purposes, as a starting point to identifying relevant options.

The AgWater Solutions project, carried out between 2009 and 2012 in South Asia and Sub-Saharan Africa, provides a potential blue-print for an approach to improve AWM in the Dry Zone. The project aimed to identify investment opportunities in AWM with high potential to improve the food security and income of poor farmers, by developing ways to assess the potential of various water management technologies; and business models and plans for disseminating and scaling up the most promising technologies. The key to the AgWater Solutions approach is building from existing farmer-driven initiatives in small scale AWM, recognizing that small private irrigation is outpacing large irrigation schemes in many parts of the world. A critical component of the approach is initiation of dialogue among policymakers, implementers, private-sector representatives, donors and farmers on recommendations and business models.

The AgWater Solutions approach recognizes that the success of AWM technologies is critically dependent on exploring the specific social, environmental and institutional context, as well as bio-physical conditions. An important lesson from the project is the need to provide a range of AWM options, since even within the same farming system, different farmers will have different needs, financial resources and capacity. Similarly, the business models for scaling out identified solutions must also be developed for each specific case. Examples of solutions which may be relevant for the Dry Zone include:

- Small farm dams in Madhya Pradesh, where farmers put aside around 10% of their land to construct rainwater harvesting structures to provide supplementary irrigation in dry spells during the wet season, and allow cultivation of a crop during the dry season. Studies indicate that payback period is around 2-3 years. Uptake of dams was encouraged by a government subsidy of up to 50% of construction costs (IWMI 2011).
- Establishing private sector manual well drilling businesses in Ethiopia, to improve affordable access to shallow groundwater resources. The Government of Ethiopia sees manual well drilling as an effective and scalable way to develop Ethiopia's shallow groundwater reserves to benefit smallholder farmers (http://awm-solutions.iwmi.org/Data/Sites/3/Documents/PDF/manual-drilling-investment-opportunity-in-ethiopia--final-1.pdf)

- Business plans for small private irrigation service providers in Tanzania, to provide affordable access to motorized pumping for those who do not have the means or skills to buy, operate and maintain a pump (http://awm-solutions.iwmi.org/Data/Sites/3/Documents/PDF/publication-outputs/learning-and-discussion-briefs/irrigation-service-providers-a-business-plan.pdf).

AgWater solutions also developed methods for regional mapping to assess which solutions have potential in different areas, based on a combination of geographic (GIS) data analysis, biophysical and economic predictive modeling and crop mix optimization tools; and watershed assessments based on stakeholder consultations to develop scenarios around AWM interventions to review the likely impact on livelihoods and water resource, considering implications for equity, gender, poverty reduction, water quality, water quantity and other natural resources (http://awm-solutions.iwmi.org/mapping.aspx). These methods, which require significant consultation, could be applied as part of more detailed follow-up studies in the Dry Zone.

Table 4.4 Agricultural water management interventions at different scales and contexts (adapted from Awulachew et al., 2010)

Scale	Water Source	Water Control	Water Lifting	Conveyance	Application	Drainage & Reuse
Farm-level	Rain water	SWC Farm ponds Cistern/ subsurface ponds Roof water Recession agric.	Treadle pumps Water cans	Drum Channels Pipes	Flooding Direct application Drip	Drainage of water logging Surface drainage channels Recharge wells
	Surface water	Spate and flooding Diversion Pumping	Micro pumps (petrol, diesel) Motorized pumps	Channels Canals Pipes	Flood & Furrow Drip Sprinkler	Surface drainage channels for irrigation, water logging
	Ground water	Spring protection Hand dug wells Shallow wells	Gravity Treadle pumps Micro pumps (petrol, diesel) Hand pumps	Channels Canals Pipes	Flood & Furrow Drip Sprinkler	Surface drainage channels Drainage of water logging Recharge wells
Community or catchment	Rain water	SWC Communal ponds Recession agriculture Sub-surface dams	Treadle pumps Water cans	Drum Channels Pipes	Flooding Direct application Drip	Drainage of water logging Surface drainage channels
	Surface water	Spate and flooding Wetland Diversion Pumping Micro dams	Micro pumps (petrol, diesel) Motorized pumps Gravity fed	Channels Canals Pipes (rigid, flexible)	Flood & Furrow Drip Sprinkler	Surface drainage channels
	Ground water	Spring protection Hand dug wells Shallow wells Deep wells	Gravity fed Treadle pumps Micro pumps (petrol, diesel) Hand pumps Motorized pumps	Channels Canals Pipes (rigid, flexible)	Flood & furrow Drip Sprinkler	Surface drainage channels Recharge wells and galleries
Sub-basin, basin	Surface water	Large dams	Gravity Large scale motorized pumps	Channels Canals Pipes	Flood & Furrow Drip Sprinkler	Surface drainage channels Drainage re-use

5. Priority interventions

Analysis of existing conditions and programs indicates that strategies to secure water for village use (domestic and livestock) centre mainly around local small-scale storage of surface water; and accessing groundwater through wells. Wells are particularly important for drinking water, as both quantity and quality of surface stores often deteriorate in the dry season.

In the context of agriculture, three main strategies are being used to manage water scarcity and variability: formal large-scale irrigation systems (gravity fed from storage; pumped from rivers; and pumped from groundwater); informal small-scale supplemental irrigation from a range of sources, with groundwater becoming increasingly important; and rainwater harvesting and storage in small multi-purpose reservoirs. These are also the interventions that emerged as highest priority in village consultations.

Two other issues emerged as high priority, though not reported as concerns at village level. The first is the important role that watershed management approaches, at a range of scales, can play in improving availability and quality of water and protecting water infrastructure. By retaining water within the landscape in the soil profile and shallow aquifers, significant gains can be made in overall agricultural productivity as well as replenishing groundwater stores and reducing or reversing land degradation due to erosion and loss of vegetation cover.

The second is the need for a more strategic approach to water resources planning and management. Although at a village level the distinction between domestic and agricultural water supplies is often not meaningful, planning and implementation of programs in the two sectors are separate, and spread across a range of agencies with limited coordination. Access to and quality of data on water-related issues is a serious constraint to a coordinated approach.

Based in this analysis, we have considered interventions in five domains:

1. Improvement of formal irrigation infrastructure
2. Groundwater interventions for domestic and agricultural supply
3. Rainwater harvesting and storage
4. SWC /watershed management
5. Water resources planning and information

For each area, we have identified opportunities and priorities, as well as main factors constraining implementation; knowledge gaps; and potential entry points for LIFT.

5.1 Improving the performance of formal irrigation systems

Provision of formal irrigation infrastructure is an important priority for the Myanmar government, who have put considerable effort into construction of irrigation schemes over the last 20 years, raising the area irrigated in the Dry Zone to a nominal 0.38 m ha, or around 5% of total area, and 12% of cultivated area (JICA 2010).

The actual area irrigated is much lower. For the dry season of 2011, IWMI estimated total irrigated area (including both formal and informal irrigation) at 0.27 m ha. In all visited irrigation schemes, the effective irrigated area was considerably smaller than the nominal command; for example, in

Nyaung-U, WRUD reported that in 2012-13 only 26% in the wet season and 15% in the dry season of nominal area was actually irrigated. A government report released by the Auditor General's Office in 2012, found that nationally "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"[1], and that some reservoirs and diversion dams could not supply water at all. The report recommended that inefficient schemes be abandoned rather than rehabilitated.

Our analysis (Report 1) and that of LIFT (2012), amongst others, suggest that this does not, on the whole, reflect a physical shortage of water but is due to a complex set of factors including operation and maintenance issues, availability of power for pumping, and inappropriate siting and soils. This situation resembles the problem of poor performance in irrigation systems observed in many other places, linked to a vicious cycle of bad construction, deferred maintenance, and premature rehabilitation. In this light, we argue that improving performance of formal irrigation infrastructure through rehabilitation will only address the symptoms, rather than tackling the roots of the problem: deferred maintenance.

There is thus a need to address issues constraining the operation of existing systems before investing in new development. Village surveys (Report 2) indicate that unequal water distribution that causes crop failures and conflicts (particularly between head and tail-end farmers), often results from lack of clear and transparent institutional arrangements, and therefore the water management committees and WRUD are unable to regulate and coordinate water distribution and related activities. In Indonesia, the 'golongan' rotation system is used to ensure equitable water sharing in time of scarcity, by linking a pre-determined water delivery schedule with farmers' cropping calendars. This approach, which staggers planting dates successively among sections of the irrigation systems, requires farmers to work in groups, strengthening local institutional arrangements (Gruyter, 1933; Pasandaran, 2010). It could provide an effective entry point for improving water management in existing systems in the Dry Zone. A more detailed description of the 'golongan' system is provided in Appendix 5.

Irrigation by itself is unlikely to make a difference to the incomes and livelihoods of farmers. Investments in output markets, such as the development of commodity exchange centres, wholesale warehouses and storage facilities are important, so that farmers are able to procure a fair price for their outputs. Additionally, investments are also required in the input market, so that farmers are able to procure high quality seeds, fertilizers and pesticides. Creation and extension of credit facilities for farmers to buy inputs in a timely manner are also important.

Myanmar as a country is moving from a centralized to decentralized policies. If reform and re-vitalization of formal irrigation systems is to take place, then it will call for a redefining and re-understanding of the roles, responsibilities, tasks and expectations of the government and the communities, keeping in mind the history of the development of irrigation infrastructure. This will

[1] http://www.mmtimes.com/index.php/national-news/1055-committee-urges-action-on-failing-irrigation-projects.html

likely require an increase in capacity across the board, especially at the village and community level. A better understanding of the tradeoffs, and ways to negotiate those tradeoffs, is required.

Three further issues complicate investments in formal irrigation in the Dry Zone.

- Government policies mandating production of paddy in irrigated lands, though now being relaxed, significantly hamper the ability of farmers to make the most efficient use of available water; since input costs for summer paddy are high, a poor crop can result in catastrophic losses for farmers
- Government subsidy in irrigation development is not linked to government policy in agriculture (i.e. pricing of agricultural products, cost of inputs like fertilizers, pesticides, and seeds, harvesting). Given current fragmented subsidy schemes and mechanisms, the role of irrigation systems should be viewed in relation to its role in providing farmers' access to water to improve their livelihoods, increase farmers' living standards and reduce poverty. In this context, water charges can be applied to encourage better systems Operation and Maintenance (O&M), but should not be viewed as source for system full cost recovery. Charges for water seem to be a standard 9000 kyat per hectare per season for full dry season paddy irrigation; 6000 kyat for non-paddy crops in the day season and 3000 kyat for wet season, regardless of the type of system. WRUD staff in Nyaung-U estimated the actual cost for PIPs (including pumping and maintenance but excluding capital costs) at around 40-45,000 kyat per hectare. In summary, the role of irrigation systems should be viewed beyond the cost benefit analysis, whether or not these systems are economically viable.
- For PIPs, WRUD report that insufficient power supplies seriously hamper effective operation. Unless power for pumping can be guaranteed, investments in construction or rehabilitation of PIPs may be lost.

Experience in other countries indicates that although formal irrigation schemes can be an effective means of raising agricultural production, they are not necessarily an efficient way of addressing rural poverty, since benefits tend to accrue most to larger, semi-commercial farms. In livelihood terms, formal irrigation schemes serve only a small proportion of the households (since they serve at most 12% of cultivated land); although village surveys indicate that benefits also accrue to the landless, through employment of labour.

Constraining factors

Government agricultural policies relating to summer paddy production and crop diversification are important drivers of irrigation development and management. It is essential to link and align current water resource management policy and practices with the country's agricultural policy in general, and specifically with crop planning. A comparative review of the two policies is urgently required as a precursor to further investment in irrigation.

Past irrigation development has been driven by government policies and initiatives, and has not necessarily reflected farmers' needs and priorities. Approaches are needed to allow local communities to represent their development needs and aspirations in irrigation development, and to take a more active role both in determining the type of development that is undertaken, and in implementing and managing irrigation systems.

Knowledge gaps

Before pursuing investments in large-scale irrigation infrastructure, further information is required on the following:

- Government policy objectives relating to irrigation, and its role in agricultural and rural development in general
- The relative effectiveness of different modes of irrigation (gravity schemes, PIPs, groundwater) in terms impacts on yields, farm incomes and poverty, livelihoods and cropping patterns for landed, marginal and landless farmers
- The overall effectiveness of irrigation investments to increase incomes. With farmers purchasing inputs on loans from agents, and the middlemen controlling the output market, farmers find it challenging to get fair prices and make reasonable profits. Business models that smooth the output and input markets would be an important consideration
- An assessment of water resources, existing cropping patterns, irrigation practices, water usage, and projected increase in use
- Impacts of alternative policy instruments, such as crop policy, subsidy of inputs, and higher crop prices, on incomes and livelihoods

Potential entry points for LIFT

Before LIFT engages in major rehabilitation programs within existing formal irrigation schemes, or in construction of new large-scale schemes, an assessment is required of the complex mix of physical, technical and institutional challenges impeding the effectiveness of current schemes. A potential entry point for LIFT is an assessment of the relative effectiveness of different modes of irrigation (gravity schemes, PIPs, groundwater) in terms impacts on water and energy productivity as well as yields, farm incomes and livelihoods. This could be undertaken at two levels: a comparative assessment across existing large schemes; and community based analysis of outcomes at village level.

There is also an opportunity to reduce risks in existing systems by rationalising water delivery. The current operations are theoretically negotiated through WUAs, but in practice appear to be ad hoc. Introduction of pre-scheduled water delivery using the golongan approach described above has the possibility to affect a large increase in the efficiency of existing schemes for a small cost. A pilot of golongan in an existing system could be used as an entry point for LIFT to work with government to better link water resources planning with crop planning.

5.2 Groundwater interventions

Groundwater plays an important role in domestic water supply in the Dry Zone, and is increasingly being used for irrigation, but there is limited information on the extent and sustainability of the resource. The current study does not support the view of great abundance, but suggests a more moderate resource which, whilst extremely important for the Dry Zone, must be planned and developed carefully, in conjunction with surface water, to ensure utilization over the long term.

A balance is needed between a precautionary approach to ensure sustainable management over the long term, and development of groundwater to address the pressing present needs. The heavy reliance on groundwater for domestic and drinking water for people and livestock means that if significant drawdown did occur due to over-exploitation, the consequences for communities could be severe; already there are some examples documented in Report 2. In addition, investment costs for groundwater development are considerable; for large-scale systems established by government that rely on deeper tube wells with large capacity (electric) pumps and in relative terms for private systems setup by farmers or communities. A balanced approach would include:

- conjunctive use of surface and groundwater: developing groundwater primarily to address shortfalls in surface water either spatially (areas where alternatives are not available or costly) or temporally (as a seasonal supplement when surface water is depleted)
- prioritizing the use of deep wells for domestic and livestock uses, which are low volume, high value and so can justify the higher costs of installation and operation by the security of supplies
- an assessment of groundwater resources at district level as the basis for planning and managing groundwater utilization (see Section 5).

On this basis, we recommend that groundwater investment in the short term should focus on two areas: securing village / domestic supplies using deep tube wells; and supporting development of supplementary irrigation from shallower aquifers. Shallow aquifers can be prone to seasonal drying-out and so a balance is needed between attempting to protect high value domestic resources and ensuring adequate performance of irrigation wells. The provision of drinking water must be the highest priority, and plans to expand irrigation development should not compromise current or future access to drinking supplies (for people & livestock). In some areas multi-level aquifers can be accessed economically, which potentially enable segregation if area-specific planning for resource development and management can be put into effect based on improved information as described in Section 5.5.

Groundwater for domestic supplies

The MICS (2010) survey indicates that in rural areas nationally, a third of rural people source drinking water from tube wells and another third from protected shallow wells. WRUD (2013a) reports that 6.65 million people in Mandalay Magwe and Sagaing have access to domestic supplies from more than 13,700 wells (two-thirds of which are deep wells). IWMI's survey confirmed the success and importance of deep tube wells with motorised pumps for village water supply. Deep wells within the village provide reliable, high quality water in all season, benefiting the whole community. After installation of deep tube wells in villages, JICA (2007) reported reduced time for water fetching, reduction in incidence of diarrhoea, dysentery and skin diseases; and increased water consumption in poor households. In most cases, such wells are used exclusively for domestic and livestock purposes (and often primarily for drinking) due to the cost of pumping. Shallow tube wells using manual or motorised lifting are also important for village supplies, but water quality and quantity from shallow aquifers is less reliable. Solidarity International (an INGO) has had success with implementing village level solar pumps for domestic supplies under a payback scheme. UNICEF also have experience with solar pumps; and ADRA have been trialling the use of solar pumping for domestic supplies.

Wells with motorised pumps providing flow at 1500 gallons per hour (6.8 m^3 /h) can provide domestic water for an average village (800-1000 people) (JICA 2007). Where deep drilling is needed, the cost of installing a well and electric pump for a village system can be as high as $40,000 (JICA 2010). JICA report a high success rate in drilling, with all 49 wells in their study capable of delivering the required volume. The IWMI study identified only one community where drilling for water had been unsuccessful.

Maintenance of pumps is an on-going concern, requiring support from local government agencies. As part of the Rural Water Supply project JICA trained engineers in pump maintenance, and instituted Village Water Committees (VWCs) to manage the supply of water and maintenance of pumps (JICA 2007).

Groundwater for irrigation

Farmers in the Dry Zone are already adopting groundwater irrigation (see Section 3.3) typically using shallow tube wells powered by small motorized pumps. They are emerging not only in rainfed areas, where expected, but also within irrigation command areas where there are shortfalls in supply: deep drainage flows generated by the schemes can be picked up and recycled by the tail end farmers. This mirror a trend observed in many parts of Asia over the last 30 years, as pumping technologies have become affordable and accessible (Mukherji et al 2010). Small scale, farmer managed pumping has significant advantages in terms of flexibility, reliability and simple operation and maintenance. Where groundwater supplies are available and sustainable, this has proved to be an affordable and effective way to increase production.

In the village surveys where various options were presented to choose from, farmers in all groups (land-owing, marginal and even landless) expressed strong preferences for shallow wells with diesel pumps for irrigation over communal deep wells with electric pumps for irrigation purposes (presumably on the grounds of cost, flexibility and autonomy). These systems access groundwater from shallow dug wells or tube wells that are typically less than 30 metres deep. Lifting is performed either manually (for small areas) or small motorized pumps that deliver between 100 and 500 m^3/day. The cost of drilling shallow wells is of the order of 100-500,000 kyat; the cost to purchase a pump is similar, depending on the size (see Report 2 and Appendix 3). Proximity[2] have developed manual treadle pumps capable of delivering 50-100 m^3/day (580-1000 gallons per hour) from depths of 6-8m; these cost less than around 15-40,000 kyat but service smaller areas. Solar pumps may also be an option but the purchase cost is high. Production systems usually involve irrigation of small areas of a few acres for high-value crops such as vegetables, for local markets or export to China. They are 'informal' in nature, financed and managed by the farmers themselves on an individual or small group basis. As an added benefit, water is commonly also used for domestic and livestock purposes. An example is described within the BOX in Section 3.3.

It is estimated that, depending on which crops are grown, groundwater recharge is sufficient to irrigate an estimated additional 110,000 of land in the Dry Zone (underlying assumptions in this analysis are given in Report 1), with almost two-thirds of that potential situated in the districts of Monywa, Shwebo and Pakokku (Report 1). These are also areas where the most prospective Alluvial and Irrawaddy Group aquifers predominate. Monywa and Pakokku in particular have limited surface

[2] http://www.proximitydesigns.org/

water irrigation, and a high proportion of rainfed lands; and viability of groundwater irrigation from relatively shallow aquifers (8-20m) has been amply demonstrated in Monywa. These districts are thus a logical starting point for further investments in groundwater irrigation.

Conjunctive development of surface and groundwater is important part of sustainable use. Surface water infrastructure, if developed strategically, can enhance recharge to shallow aquifers during the wet season. For example, villagers in Ta Ein Tel (Sagaing) reported that supplementary pumping to the village pond had improved both the quantity and quality of water in the nearby local well. Thus if the dynamics of recharge are well understood, shallow groundwater can be used as de facto “natural storage”, with the additional benefit of minimal losses to evaporation.

Constraining factors

The main factors constraining adoption of deep tube wells for domestic use are cost of installation; cost and reliability of power supply for pumping; and maintenance of pumps. Maintenance of electric pumps used for village supplies may require support from local administration. There are many possible pathways to create an enabling environment to boost groundwater-based irrigation development. These include: a) modest subsidies on drilling costs and/or purchase of motorized pumps; b) micro-finance to support establishment costs; c) site-specific advice on the preferred crops to grow during the dry seasons and other agronomic practices that maximize the market benefits; and d) technical advice on groundwater availability and opportunities for use, presented in simple formats.

Both salinity and arsenic have been problematic in some areas. In the Monywa irrigation scheme high salinity precluded the use of some wells; and the WRUD has documented high arsenic levels in some drinking water wells in the Dry Zone (WRUD 2013b). This emphasises the need for rigorous assessment of both water quantity and quality before implementing major developments.

Knowledge gaps

The success rate in drilling for water is relatively high (see above), but better hydrogeological information (see Section 5.5) could improve targeting and reduce costs of drilling.

Sustainability of withdrawals in different systems, recharge dynamics, and impacts of pumping on groundwater inputs to wetlands and base-flow in streams. Community monitoring of village wells as part of routine operation would provide valuable information. In addition, more rigorous assessment of groundwater development potential is needed, particularly in priority districts and townships, also taking into account the possibility of large increases in groundwater use for industry.

If future irrigation strategies rely more on groundwater, this poses a new set of regulatory and institutional challenges, since the different attributes of groundwater systems mean that different governance systems are needed. Creating locally adapted forms of groundwater governance that are inclusive of the involvement of high level institutions from the government along with grassroots participation is central to the success of groundwater development programs and resource sustainability over the long term. A groundwater framework/policy should be developed for the Dry Zone that would also be applicable at the national level.

Potential entry points for LIFT

- Technical support, through WRUD and / or relevant NGOs to identify priority areas for groundwater use (based on resource assessment – see Section 5.5)
- An inventory (database and maps) of existing wells and utilization, including water quality data (salinity, arsenic).
- Support for motorised deep tube wells for village (domestic and livestock) supplies
- Business models for communities to install and operate village pumps for domestic supplies, including private investors, village water committees
- Program to promote use of shallow tube-wells for small-scale supplementary groundwater irrigation (GWI) for a range of cropping systems including rainfed areas, and conjunctive use to supplement shortfalls within irrigation schemes
    - Business models for small-scale GWI, including shared investment between small groups of farmers, and supply of water by private investors
    - Agronomic advice: extension services to help farmers make best use of irrigation through crop choice and in-field water management (e.g. drip irrigation, mulching etc)
    - Work with NGOs (e.g. Proximity) to develop and market appropriate and affordable pumps and equipment
- Microfinance or loans to communities and individuals for pumps and equipment
- Regional monitoring network, possibly using community monitoring of wells, as input to groundwater assessments (Section 5.5).

5.3 Rainwater harvesting: village reservoirs and small farm dams

Ponds and small dams for rainwater harvesting emerge as the preferred option for improving water supplies for villages in many contexts in the Dry Zone. They are a simple, proven technology, already common throughout the Dry Zone. Village ponds are usually formed by earthen, stone or cement dams. They can vary greatly in size and type and provide for multiple uses including domestic, livestock watering, small scale irrigation and small businesses such as brick making and handicraft activities. Village ponds are usually managed by the community, but may be managed by the ID; or in combination by the ID and community. NGOs such as ActionAid, ADRA, Solidarity International and Proximity have considerable experience with construction and rehabilitation of village ponds: for example, Proximity renovated 260 ponds in the last year.

Irrigation Department (ID) is also involved in rainwater harvesting. For example in the Mandalay Region, the Regional Government requested support to undertake renovation and reconstruction works in addition to building new storage structures for RWH. The ID has a fleet of equipment and staff that can be utilized to undertake this work. The ID provides technical assistance while the budget comes from the Regional Government. The ID had planned to assist with 200 tanks in the Mandalay region in 2012, including construction of new ponds and renovation of old ponds, for irrigation as well as domestic water uses. Cyclone Giri in 2010 destroyed a large number of RWH structures in both the Mandalay and Magway regions (as they were not built to withstand extreme rain events), so the renovation of some of these ponds was supported by the ID.

Important lessons from the experience of NGOs in village RWH:

- There are no blanket solutions – needs must be assessed and appropriate solutions designed for each village, in the context of village livelihood patterns and resources.
- It is important to involve village communities and district/ local government agencies (GAD, DI) in planning, construction and management of village reservoirs. ActionAid and ADRA have developed participatory methods for working with communities to ensure that water interventions are closely linked into village development plans, with clear delineation of responsibilities, and endorsement and support of GAD.
- Village reservoirs can provide livelihood opportunities for the landless, for example, through payments for construction, management and maintenance, or establishment of community forests/woodlot around pond as part of watershed management (ActionAid). Cash for work has been a successful model for construction of ponds, administered through community based organisations (CBOs).

Type, design and siting of such ponds are very specific to each location, and depend on the uses. Dug earth dams are very common, but will not fit all contexts. Other options include subsurface and sand dams (formed by embankments in streambeds), and ring / turkey nest dams (above ground dams filled by pumping from rivers). Ponds may be coupled with systems to improve access (such as piped systems, pumps or access points, watering troughs for livestock etc). Evaporative losses can be reduced by constructing deeper. Seepage losses can be reduced by siting dam on areas of clay soils, compaction of the base during construction, or lining with clay. However, opportunities should also be sought to capitalise on seepage by constructing wells nearby, as seepage losses effectively recharge shallow groundwater. For example, villagers in Ta Ein Tel (Sagaing TS) reported that an unexpected side-benefit of supplementary pumping to the village pond was improvement in both the quantity and quality of water in the local well.

Village ponds can be used for supplementary irrigation, particularly in the wet season when they are being regularly replenished. However, in the dry season the imperative to conserve water for domestic and livestock use will often override, unless the capacity of the pond is large. Negotiation of appropriate use for water from village ponds requires integration of multiple users and social groups. Winrock (2012) provides guidance on the specific challenges of design, implementation and management of multiple use water systems.

Sand dams (i.e. a concrete wall built across a seasonal sandy river bed so that water is stored within the sand) can be very successful under the right circumstances. The advantages are reduced evaporation and the fact that the sand filters the water so often improving water quality. Other advantages are that construction costs are generally low and maintenance requirements are modest. They should be located where there is a seasonal river with sufficient sandy sediment and bedrock that is accessible in the river bed. An infiltration gallery and pipe can be used to extract the water directly or it can be allowed to infiltrate into the ground to recharge shallow aquifers. This technology has been tested successfully in the Dry Zone at Thea Pyin Taw village (see report 2).

If use for irrigation is planned, dedicated irrigation ponds may be preferable, to reduce water use conflicts, and because of the relatively larger volumes required. These can be situated in the fields, closer to point to use. Two models for pond irrigation are in common use internationally:

- Individually owned small farm reservoirs: have proved to be an effective way to provide supplementary irrigation to reduce the risks of double cropping in rainfed systems in areas of NE Thailand (REF) and Madhya Pradesh, India (AgWater 2012a, 2012b) which have similar agro-ecosystems to the Dry Zone. In areas with larger landholdings (> 2 ha), a commonly used model is for farmers to sacrifice around 1/10th to 1/15th of their land area to construct a store for water to be used in the dry season, or for supplementary irrigation during the monsoon season. In Dewas District, Madhya Pradesh, India a very successful program of small dam irrigation has been undertaken, where over 5000 dams have been constructed with significant gains in farm incomes (AgWater Solutions 2012b).
- Communal irrigation dams: larger communal storages constructed and managed by a group of farmers may be more appropriate in areas where farm sizes are smaller. This is analogous to village ponds, but with a smaller group of users. The size (and number of farmers involved) can vary, but a typical pond may serve around 10 ha

AgWater Solutions (2012b) provides an overview of small reservoirs for agricultural water.

Costs of village ponds vary considerably depending on size and type. The cost for a small irrigation dam serving 10 ha in the Dry Zone was estimated at around USD 6000 (IWMI workshop discussions). Average cost of ponds in Dewas was USD 2600; the payback period was three years and the cost-benefit ratio 1.5-1.9. In Dewas, the local administration offered a subsidy of 50-80,000 INR (USD 900 -1400) to encourage development.

In most cases, communities have the skills to both construct and maintain these structures, but support may be needed in the form of technical advice, community payments for labour, or access to machinery. Consultation with the community as to design, construction and maintenance requirements and responsibilities is critical. Maintenance (removal of silt, repair of wall) is required at least every 2-3 years, and in many cases annually (ADB 2007; IWMI workshop discussions). Unless the community commit to maintaining the structures, investment will be lost. In this respect, there are some INGOs such as Solidarity International and IDE that have set up water management groups in the village to manage and maintain the RWH storage infrastructure. Solidarity International for example set up such water management groups in 15 villages in the Dry Zone in 2011 and adopts a number of mechanisms to try and ensure that the groups remain operational once the INGO exists from the village. A key issue is also proper spillway design, and maintenance of the spillway. Many small dams fail because they are overtopped in a flood, often because the spillway is inappropriately designed or because it has been neglected (e.g. vegetation growing in it).

The viability of ponds and small dams is often reduced due to problems of siltation and collapse of the embankments. Measures that reduce flood runoff and sediment transport in the catchment zones should be carried out in conjunction with the construction or rehabilitation of reservoirs. There are many soil and water conservation techniques that have been developed to reduce runoff and erosion. Such techniques comprise area treatments, drainage line treatments and afforestation and pasture development and can include: hillside terraces, stone bunds, and vegetation bunds, gully plugs, earthen and stone banks as well as planting of trees, grasses and shrubs. In addition to reducing runoff and erosion these interventions enhance groundwater recharge and can be designed to meet other household needs. For example vegetation planted can contribute to fuel, fodder, timber, fruit and fibre requirements. Relevant techniques for the Dry Zone are described in detail in Carucci (1999); see also Section 5.4.

Constraining factors

Key constraints for effective adoption of small reservoirs are cost of construction; and commitment of communities to on-going maintenance and watershed management. The fact that so many small reservoirs in the Dry Zone require rehabiltation is a testament to the difficulty of ensuring long-term maintenance.

Evaporation is a major problem for rainwater harvesting, with 50-100 % losses due to evaporation.

Knowledge gaps

- Technical and social approaches to ensure long-term maintenance of reservoirs
- Dynamics of interactions between surface water and shallow groundwater, and potential to use small reservoirs/sand dams to recharge shallow aquifers
- Evaluation of existing storage dams and other RWH technology, including siltation and lifespan of the dams
- Economic analyses of costs involved in construction, maintenance, rehabilitation of RWH infrastructure
- Assessment of the role and sustainability of water user groups in the Dry Zone in relation to the management and maintenance of RWH storage infrastructure at the village level
- Technical studies to determine suitable soil types and locations for RWH structures

Potential entry points for LIFT

- There is potential to scale up existing projects to construct and/or renovate village ponds, small reservoirs and sand dams, being implemented by NGOs including ActionAid, Proximity and ADRA. Prior to scaling up, a preliminary review should be conducted of outcomes of the projects, including sustainability of structures and maintenance.
- Technical support and guidelines for improvements in design, particularly to capitalise on the potential to use seepage to recharge shallow aquifers
- Watershed management programs in catchment areas of reservoirs to protect inflows and water quality.

5.4 SWC / Watershed management

Soil and water conservation (SWC) approaches at either field or catchment scales did not emerge strongly as a priority from village consultations. However, there are two important reasons to give serious consideration to SWC programs in the Dry Zone at a range of scale. Firstly, land degradation is wide-spread and on-going, with impacts on production (through loss of topsoil, low nutrient status), loss of productive land (through gullying and loss of vegetation cover), and impacts on infrastructure (silting up of ponds, sedimentation in canals, damage to pumps from high sediment loads in water). Secondly, agriculture in the Dry Zone is, and will remain for the foreseeable future, dominantly rainfed. SWC approaches both within field and at landscape scales are essential for managing water effectively in rainfed systems.

At the field scale, consideration should be given to more widespread implementation of techniques to enhance infiltration and water retention in the soil profile with the objective of stabilizing and increasing crop yields by increasing the effectiveness of rainfall. Appropriate techniques are well known: Cools (1995) reported the use of a range of traditional SWC practices in the Dry Zone (overflow bunds, gully plugging with rocks or crop residues, strip cropping, agroforestry techniques); other promising approaches include deep tillage, reduced tillage, zero tillage, mulching, planting basins and the use of crops with low water requirement. Kahan (1999) provides a detailed manual of SWC techniques specifically targeted for the Dry Zone. Such techniques are likely to be most effective:

- around the periphery of the Dry Zone, in areas where rainfall is broadly sufficient to enable a non-irrigated wet season crop in most years; and
- lowland areas that, in many years, already achieve a summer crop based on residual moisture. Such practices might also be beneficial in irrigation schemes where water *per se* is not limiting but the electricity costs of pumping make water conservation desirable.

In-field SWC techniques are basically agronomic practices, and would need to be introduced as part of agricultural extension services. Livestock management and impacts of free grazing are significant drivers of erosion, particularly in the uplands where sheep and goats are common, and grazing management is an important component of watershed management approaches.

Similar techniques, applied at landscape scales, can be used to prevent erosion, improve water retention and infiltration and enhance recharge to shallow aquifers. The primary aim is to slow the rate at which water moves through the landscape. Approaches include checkdams, vegetated strips, infiltration basins and flood spreading (see van Steenbergen et al. 2010, 2011). Management of vegetation cover is a key component of watershed management, through conservation of existing forest patches (e.g. through Community Forest Programs), forest planting, agroforestry and enclosures to reduce grazing pressure and allow regrowth. Vegetation planted can contribute fuel, fodder, timber and fruit to communities. Conservation zones can be used to protect riparian vegetation and reduce river bank erosion: Welthungerhilfe (WHH) report that a 30m exclusion zone along streams was previously enforced but has been abandoned in the last 20 years. Such catchment approaches can be vital to reduce sedimentation of small reservoirs. It is essential to match interventions (and incentives) to local conditions: in the consultation workshop, examples were cited where contour banks had been unsuccessful (banks broken, trampled by stock); while hedgerows and vetiver grass banks had been much more effective. Successful programs usually had a dual focus on both water retention and erosion prevention.

In many cases, the benefits from watershed management projects may not be apparent for several years, and may accrue downstream, outside the areas where projects are implemented. Cools (1995) points out that participatory approaches may not be appropriate for SWC at village to watershed level, since other, more obviously pressing priorities may override, addressing the symptoms rather than the cause. It is important that the public good nature of the programs is recognised, and the costs shared accordingly. Incentives may be needed for farmers to undertake watershed management activities. Under the UN Human Development Initiative (HDI), fertilisers were provided to participating farmers as incentives for erosion control: this was generally considered to be a successful incentive. Micro-credit programs were not generally successful for watershed management / soil conservation programs. Current programs under GRET, Solidarity International and others emphasised the importance of finding appropriate incentive structures to involve farmers and communities, since benefits are not immediate. Although communities often express initial support, it is difficult to maintain support, particularly for programs such as grazing management

In a policy sense, the Government has recognised the importance of watershed management. Forestry Department instituted a Watershed Management Program to restore degraded lands in the catchments of newly constructed dams, to prevent erosion and reduce sedimentation. The Dry Zone Greening program begun in the early 1990s focused on tree planting (particularly eucalyptus) in areas including Monywa and Magwe; resulting tree cover can be seen in these areas, but this program is no longer active. Land use planning and soil conservation programs are the responsibility of the Land Use Division of the Ministry for Agriculture, but the Division currently has limited resources and capacity for new programs. In general there are few restrictions on land use imposed, except within the government irrigation areas (managed by ID / WRUD).

Support of local communities is critical in implementing watershed management programs, and it is important to involve the village chairman / administrator, and where possible to use existing community structures. Village elders are able to explain the objectives of programs to communities, and ensure that programs have on-going support. In administrative terms, the township is the key level, since this is the level at which local works are carried out by government – township chairman and development committees must be involved in planning and organizing programs. Permission for significant works is required from the Division level administration.

Internationally, there have been some spectacular successes in applying these techniques at scale to reverse land degradation, which can provide important lessons for implementing projects in the Dry Zone. In the Loess Plateau in China a project was funded jointly by the World Bank and the Chinese government, to reduce poverty and environmental degradation over more than 15,000 km^2 of the Yellow River Catchment, impacting more than a million farmers. Rehabilitation involved a combination of land development and erosion control works (terracing, gully control, sediment control dams, agroforestry, grazing management); and institutional development (training, research and technology transfer). The success of the project is attributed to

- well-designed technical packages which generate incomes for the local communities
- strong ownership at different levels (farmer to national government) –
    - interventions were adapted to the requirements of each watershed, and local communities developed their own plans
- effective project management with rigorous monitoring and evaluation
- scaling up from successful pilot activities
- recognition of the "public goods" nature of the project, with costs borne jointly by project farmers, and local and central governments.

In the Tana Basin of Kenya, integrated river basin management is being implemented across a catchment of 126,000 km^2. Scaling up is achieved through 56 Water Resources Users Associations, which are developing and implementing Sub-Catchment Management Plans, involving a wide range of local measures, with funding from a range of sources (Knoop et al 2012).

Constraining factors

At farm scale, Cools (1995) observed that for poor farmers with limited land area, SWC technique may be too expensive, in terms of both land and labour; and concluded that external financial support may be needed to implement SWC works.

At watershed scale, the most serious constraint may be getting the necessary buy-in from higher levels of government to coordinate programs across large areas, and developing mechanisms to motivate communities to participate in such activities.

Knowledge gaps

A review of the outcomes of programs conducted by UNDP, FAO and the government of Myanmar under the UNCCD, Greening of the Dry Zone and Watershed Protection programs would be a good starting point for designing new initiatives. This could include a targeted sediment monitoring study to gauge the success of past programs in controlling erosion.

Potential entry points for LIFT

At field scale: build SWC techniques and advice into all LIFT agricultural projects

At village scale: watershed management as an essential component of pond construction and rehabilitation, with opportunities for employment and income benefits.

At river basin scale:

- Watershed management programs were established in the 1990s -2000s for existing irrigation dams jointly between Irrigation Department (responsible for the dams) and Forestry Department (responsible for the watersheds); reports of these programs should be available. ID is concerned that the dams are silting up quickly, and that the nominal lifespan of >50 years may be reduced to 20-30 years. Follow up studies on the outcomes of these projects (including sediment studies in reservoirs) could provide a useful starting point for design of future programs.
- Programs at basin scale will not be successful unless they address on-going degradation and deforestation in the mountainous headwaters of the Dry Zone rivers (including the Irrawaddy), which lie outside the Dry Zone. LIFT could play a role in engaging Government (though Forestry Department and Irrigation Department) to re-invigorate or redesign existing watershed management programs at national level. This could include establishment of a sediment monitoring network in conjunction with the appropriate government ministry/department.

5.5 Water resources planning and information

Achieving water security in the Dry Zone requires investment in both hydraulic infrastructure and the institutions needed to manage water effectively. This investment must be carefully planned and managed in order to avoid sub-optimal outcomes. A comprehensive development strategy is needed to guide future water resources investment, as part of a larger Irrawaddy Basin Master Plan. Without this guidance the danger is that future investment will occur, as in the past, in an ad-hoc fashion with limited impact and increased risk of unsustainable practices.

In 2005, an inter-Ministry Task Force instituted a process for strategic planning of integrated water resource management (IWRM) nationally with the support of Economic and Social Commission for Asia and the Pacific (ESCAP) and FAO. This process established strategic goals and mechanisms for monitoring and reporting; and recommended the establishment of a national Water Commission (ESCAP 2006). As of October 2012, it seems that this recommendation was still awaiting action by MOAI (Bo Ni 2012).

This study has identified two areas where targeted inputs could make an important contribution: improvements in the management of water-related data; and completion of hydrogeological studies for the Dry Zone as the basis for a groundwater management plan.

Management of water-related data

A major hindrance to the current (and previous) studies has been the lack of easily accessible data. Most data are dispersed across government departments and often held at division and district level. Some information is only available at individual scheme level. There is an urgent need to establish an effective water-related data management system, comprising contemporary monitoring networks underpinned by appropriate data collection protocols and modern, easily accessible, databases and analyses tools. The development of such a system must be a government owned process and should be a nation-wide endeavour. However, a scoping study undertaken in the Dry Zone would be a useful first step in development. Such a system would greatly facilitate water resources planning in the Dry Zone (and elsewhere).

As a first step, a collaboration could be established between MOAI (WRUD), Ministry of Health, UNICEF and relevant NGOs (most already contribute program data to MIMU) to collate and make available existing information on groundwater wells (location, monitoring of groundwater levels, water quality). This is an important dataset for planning and managing initiatives in both domestic and agricultural water supply. A parallel initiative could be established between MOAI and Department of Meteorology and Hydrology to collate existing information on surface water (river flow monitoring, dam location and levels etc). In the context of water management, data on water utilization (e.g. volumes pumped and diverted from both surface and groundwater) is also extremely useful, though rarely available. Nevertheless efforts should be made to collect and collate any data that maybe available.

Groundwater resource assessment

This study has confirmed the growing importance of groundwater in both domestic water supply and irrigation in the Dry Zone. However, it has also found that, in contrast to surface water, the resources are relatively limited. The renewable recharge is less than 2% of the total surface water resource. In places there are also water quality constraints. Continued development, without an assessment of the available resource, runs the risk of lost investment through over-exploitation and inappropriate siting of wells. A necessary precursor to any large-scale program of groundwater development is an appraisal of recharge, sustainable yield of aquifers and water quality, relative to current and planned use. The basis for such an assessment exists in work begun by Drury (1986) comprising 11 map sheets of the hydrogeology of the Dry Zone at district scale. Supplemented by new studies using remotely sensed data (Min Oo and Thein 2013), these maps would provide useful indicators for regional planning purposes. This information could be used to plan and establish a regional groundwater monitoring network at critical points across the Dry Zone.

The study should also examine links between surface and groundwater, and opportunities for conjunctive management. Surface water infrastructure, if developed strategically, can be used to enhance recharge to shallow aquifers during the wet season. If the dynamics of recharge are well understood, shallow groundwater can be used as de facto "natural storage", with the additional benefit of minimal losses to evaporation.

A comprehensive resource assessment would provide the basis for a strategic approach to groundwater development, as well as operational information for siting of wells. An important outcome of the study would be information to prioritise uses of groundwater in different areas and contexts; for example, in areas that are heavily dependent on groundwater for drinking and domestic uses, and supplies are limited, it is essential to secure these against agricultural drawdown.

Constraining factors

Strategic Water Resource planning is the domain of the government, and cannot proceed without their full commitment. Responsibility for water resources is currently spread across not less than 15 government agencies with no lead agency.

Potential entry points for LIFT

Evidence-based decision making is currently hindered by both the lack of water-related data and its general inaccessibility. As a result, as the DG of WRUD acknowledged, decision-makers are currently "flying blind". The development of a comprehensive data management system would make a significant contribution to evidence based decision making. It is essential that the development of such a water data management system is a government "owned" process.

Water-related data

- Support collaboration between MOAI and Department of Meteorology and Hydrology to collate existing information on surface water (river monitoring, dam location and levels etc) and water utilization
- Support collaboration between MOAI (WRUD), Ministry of Health, UNICEF and relevant NGOs to establish a database of groundwater wells (location, monitoring of groundwater levels, water quality)
- Support a Dry Zone scoping study to evaluate the potential for establishing an effective water-related monitoring and data management system as a first step in a comprehensive nationwide undertaking, encompassing all relevant government and non-government agencies.

Groundwater assessment

- Work with WRUD, Department of Development Affairs (DDA) and the Department of Geological Survey & Mineral Exploration, Ministry of Mines to
    - Update, finalise and publish the draft maps of hydrogeology of the Dry Zone compiled by Drury (1986)

- Collate a database of groundwater wells, building from data held in local WRUD offices (see above)
- Extend work by Min Oo and Thein (2013) in Nyaung-U township, combining Remote Sensing and GIS methods to assess groundwater potential, to the entire Dry Zone
- Commission strategic research on groundwater recharge processes and dynamics for the major aquifers
- Conduct a structured survey of well-drilling companies and individuals to capture informal local knowledge of the location, extent and reliability of groundwater resources

6. Summary of Recommendations

The Dry Zone faces two main challenges relating to water: reliable supply of safe water for drinking and domestic purposes; and access to water to sustainably increase agricultural production, food security and incomes. At a village level in many cases the distinction is not meaningful, as village water supplies (particularly in the form of small dams and wells) are used for multiple purposes; and provision of domestic water impacts directly on food production through availability of water for livestock and home gardens. In the context of a semi-arid monsoonal climate, with average annually rainfall generally greater than 600mm and several major rivers, the issue is not absolute scarcity of water, but seasonal, annual and spatial variability. Three main strategies are being used to manage variability: rainwater harvesting and storage in small multi-purpose reservoirs; accessing groundwater through dug wells and tube wells for domestic and livestock uses, and increasingly for supplemental irrigation; and formal irrigation schemes.

The heterogeneity of the Dry Zone in terms of physical environment (soils, topography, rainfall), farming systems, access to water, infrastructure (roads and electrification, as well as water-related infrastructure) results in significant differences in development opportunities and priorities between villages, even over quite small distances. This means that there are no blanket solutions: the details of water-related interventions must be shaped with each community. It is important that water interventions are embedded into broader village livelihood strategies and take account of the full range of uses, rather than a focus on domestic supply separate to other needs. Existing studies and agencies working in the area emphasize that there is good understanding of issues and potential solutions within local communities and agencies. The need is not so much for new technologies, but for approaches to support implementation; and refinement and targeting of known technologies.

We have identified five priority areas for consideration in LIFT programs, the first three coming from community priorities and the last two from a broader perspective.

Formal irrigation schemes: it is recommended that before LIFT engages in major rehabilitation programs within existing formal irrigation schemes, or in construction of new large-scale schemes, an assessment is needed of the complex mix of physical, technical and institutional challenges impeding the effectiveness of current schemes; including the impact of government policies relating to agricultural development, and how these align with water resource management objectives. A potential entry point for LIFT is an assessment of the relative effectiveness of different modes of irrigation (gravity schemes, PIPs, groundwater) in terms impacts on water and energy productivity as well as yields, farm incomes and livelihoods. This could be undertaken at two levels: a comparative assessment across existing large schemes; and community based analysis of needs and outcomes at village level. A trial of the golongan system of water delivery management could be used in an existing scheme to reduce risks by rationalising water delivery; and as an entry point for LIFT to work with government to better link water resources planning with crop planning.

Groundwater interventions: we recommend that groundwater investment should focus on two areas: securing village / domestic supplies using tube wells; and supporting development of small-scale supplementary irrigation. Deep tube wells provide reliable, high quality water in all seasons for domestic use, with benefits for the whole community. Farmers are already adopting groundwater irrigation using shallow tube wells powered by small motorized pumps in rainfed areas, and also within irrigation command areas where there are shortfalls in supply. Our analysis suggests that an additional 110,000 to 330,000 ha of groundwater irrigation could be developed sustainably. Water is available in most (though not all) areas. A mix of technical and financial support is needed (business models, targeted subsidies, microfinance) to overcome high establishment costs in both sectors. A necessary precursor to any large-scale program of groundwater development is an appraisal of recharge, sustainable yield of aquifers and water quality, relative to current and planned use (see below).

Small reservoirs for rainwater harvesting and storage emerge as the preferred option for improving water supplies for villages in many contexts in the Dry Zone. They are a simple, proven technology, but type, design and siting of such reservoirs are very specific to each location, and can include a range of types including sand dams and turkey nest dams (pumped from rivers) as well as earth or stone dams to catch runoff. In general, communities have the skills to construct and maintain these structures, but support may be needed in the form of technical advice, community payments for labour, or access to machinery. Key constraints for effective adoption of small reservoirs are cost of construction; and commitment of communities to on-going maintenance (desilting, repair of embankments, clearing of spillways). Watershed management programs in catchment areas of reservoirs to protect inflows and water quality could significantly improve the effectiveness of small reservoirs, and provide opportunities for community employment.

Soil and water conservation, though not a priority from village consultations, are important in three contexts: reducing and repairing land degradation; protection of infrastructure from sediment damage; and managing water effectively in rainfed systems at both field and watershed scales. At farm scale, agronomic extension programs should include information and advice on SWC techniques; and targeted subsidies or incentives may be appropriate. At village scale, watershed management should form an essential component of pond construction and rehabilitation, with opportunities for local employment and income benefits. At watershed scale, the most serious constraints are getting the necessary buy-in from higher levels of government to coordinate programs across large areas; and developing mechanisms to motivate communities to participate in such activities. LIFT could play a role in engaging Government to evaluate and re-invigorate or redesign existing watershed management programs at national level. This could include collaboration with Irrigation and Forestry Departments for sediment studies in existing reservoirs, and follow-up studies on programs initiated in the 1990s under UNCCD.

Water resources planning and information: a comprehensive development strategy is needed at regional to national level, to guide future water resources. This is, however, the domain of the government and cannot proceed without their full commitment. Two areas where targeted inputs could make an important contribution are: improvements in management of water-related data; and completion of hydrogeological studies for the Dry Zone as the basis for a groundwater management plan. Accessible databases, held by the appropriate departments of government ministries in Nay Pyi Taw, would greatly facilitate water resources planning in the Dry Zone (and elsewhere). Continued development of groundwater without an assessment of the available resource, runs the risk of lost investment through over-exploitation and inappropriate siting of wells. A comprehensive resource assessment would provide the basis for a strategic approach to groundwater development, as well as operational information for drilling of wells.

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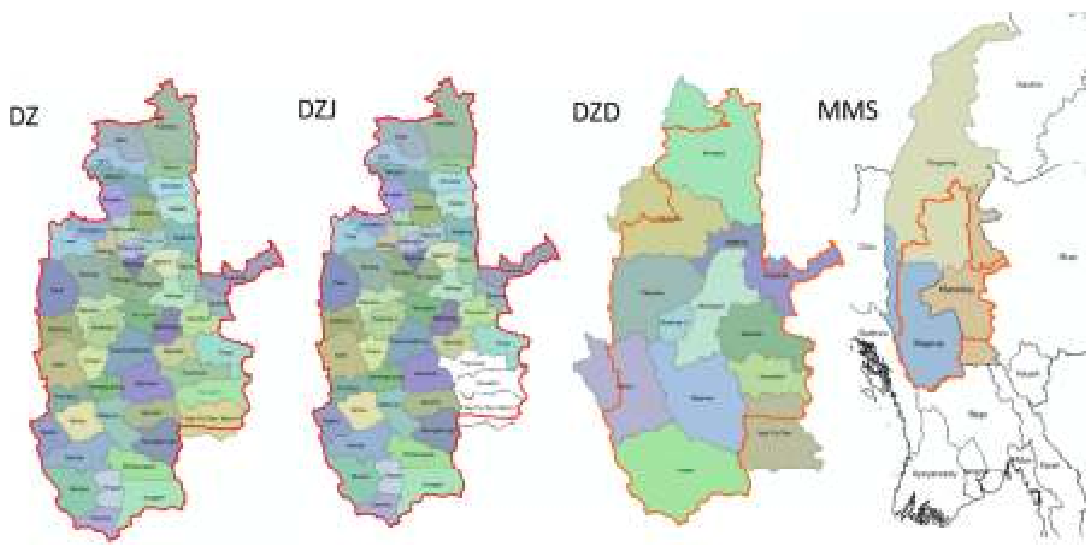
Report 3: Appendices

Appendix 1: Defining the Dry Zone

Available data for the Dry Zone is reported using a range of different extents for the Dry Zone; and in some cases, national data are only available at the level of District or Region. Reference is made to the following four different combinations of administrative areas, as shown in the figure below:

- Dry Zone (DZ) refers to the region as defined by MIMU (spatial data for extent downloaded from [www.the**mimu**.info/](www.themimu.info/) with 54 townships, including most of Nya Pyi Taw, Pyawbee and Yamethin. This is the definition used in this study.
- Dry Zone (DZJ) refers to the region used in the JICA 2010 study, which includes 51 township (excluding Pyabwe, Yamethin and Nya Pyi Taw).
- Dry Zone Divisions (DZD) refers to the 13 divisions of MMS, which incorporates some additional townships in Shwebo, Monywa, Minbu and Kyaukse, plus all of Nay Pyi Taw. The FAO Atlas (2005) reported mainly at Division level, but did not include Nay Pyi Taw.
- MMS refers to the three regions / states of Mandalay, Magwe and Sagaing. This is a considerably larger area, including northern Sagaing and eastern and western areas of Mandalay and Magwe respectively.

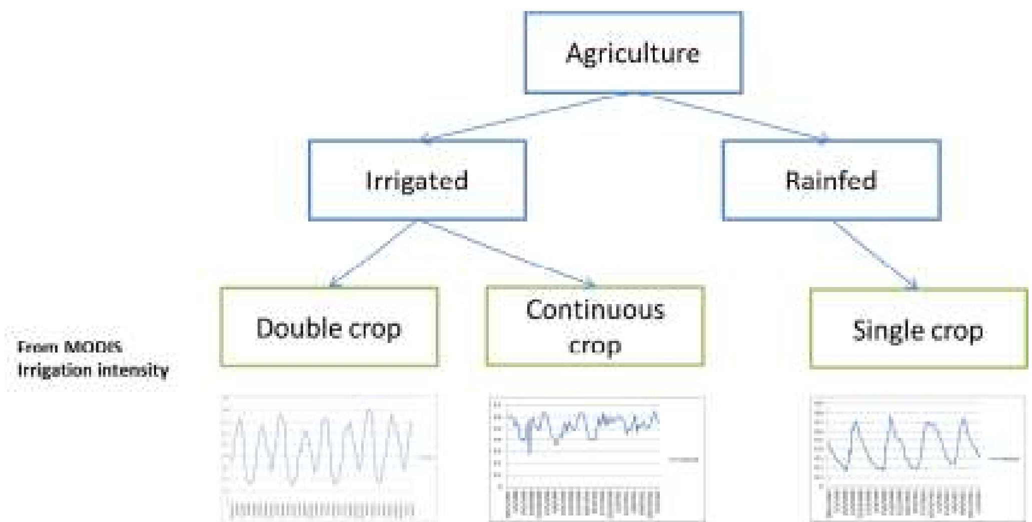


Appendix 2: Agroecosystems mapping using MODIS and Landsat

Agro-ecosystems for the DZ were mapped at regional scale by IWMI (Rajah Ameer) using multi-temporal satellite imagery. The method developed by IWMI for mapping irrigated areas, uses multi-temporal MODIS data (250 m pixel) to identify cropping patterns based on vegetation greening and senescence, represented using NDVI; and Landsat data (30 m pixel) to provide better spatial definition.

- A time-series of 16-day MODIS composites (MOD13Q1) for 2 years (2009 – 10)– a total of 46 images.
- Landsat single date imagery: 11 scenes were needed to cover the area; to get cloud free coverage, dates ranged from Jan 2009 to Oct 2010

The combined images were classified on the basis of seasonal greening patterns, to distinguish between cropped areas and natural vegetation; single cropping and double cropping; and cropping in different seasons. Stacked images were classified using ISO clustering unsupervised classification; classes were grouped and labelled using NDVI time series, and validated against Google earth imagery (see Figure 1). For agricultural classes, the following hierarchy was used:



The maps were compared with observed patterns of landcover in the DZ during field work in March 2013. In broad terms there appeared to be reasonable correspondence, although some areas of dry season agriculture were not picked up in the mapping (for example, river-bed cropping in Mandalay region).

The map should be considered as an exploratory product, which requires further validation.

More details of the methods being used by IWMI to map irrigated agriculture in Asia is given at http://ccafs.cgiar.org/node/1751 and http://www.slideshare.net/spareeth/irrigated-area-mapping-south-asia

Figure A2.1: method used in deriving agro-ecosystems map

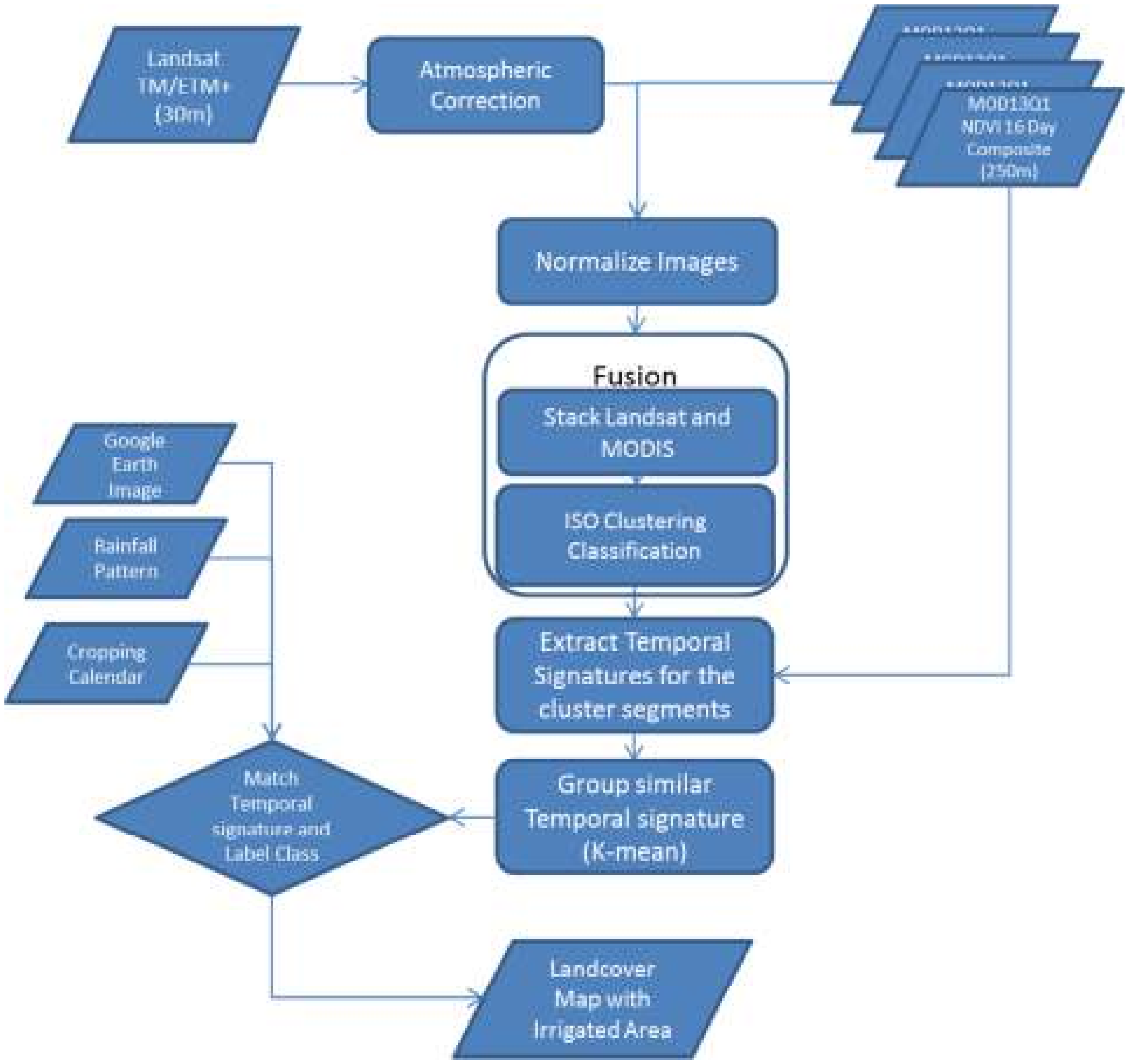
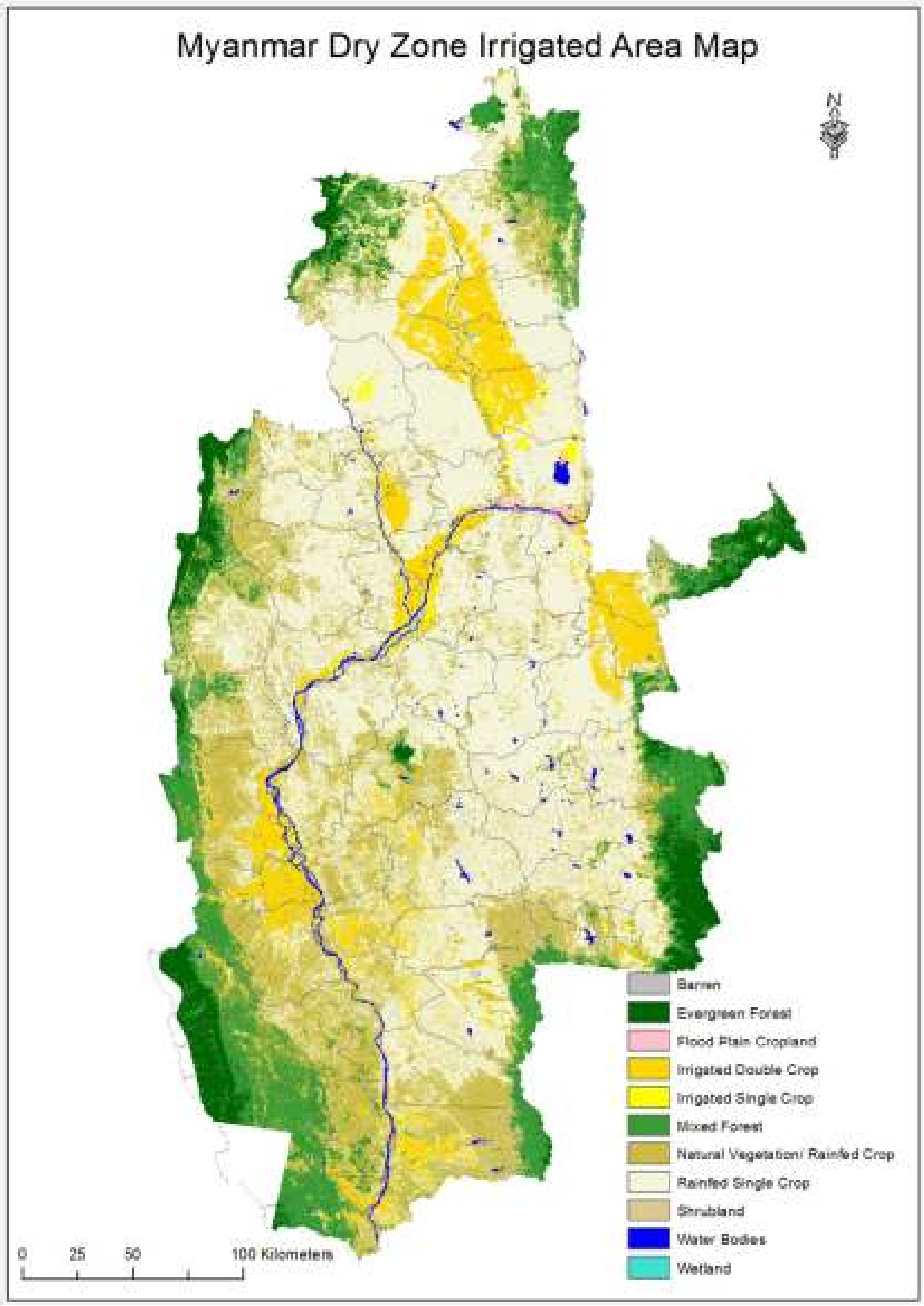


Figure A2.2: final classified image with 11 classes.



Appendix 3: Case studies of groundwater irrigation typologies

1. Monywa Groundwater Irrigation Project (Type 1)

The project was funded by UNDP and IDA and built upon pilot studies supported by the World Bank from 1983-92 in Monywa, Chaung U and Budalin Townships of Sagaing Division. The primary aim of the project was to increase crop production and farm incomes by expanding the irrigated area from 810 ha in the early 1980s to about 8,100 ha at project completion through the development of groundwater resources. A secondary aim was to strengthen the capability and inter-agency coordination of the institutions involved (World Bank, 1994).

The project area was selected from a larger area encompassing 5 Divisions on the basis of the rainfall, agricultural production, groundwater conditions, water demand, soil type, flood risk and accessibility (World Bank, 1983). Since 1995 WRUD has taken control of the scheme discharging responsibility from DOI. The system as a whole is managed by WRUD with delegation of the running of local pump operations to local farmers who have been given relevant training. Major maintenance and repairs matters are handled by WRUD.

According to WRUD hydrogeologist, Mr U Tin Maung, the scheme currently comprises of 141 deep tube wells and corresponding power supply infrastructure, pumping, water distribution and drainage systems are fully functional and irrigating 6,360 ha (Figure A3.1), or around 45 ha per well on average. The scheme is partitioned according to energy transfer as four electric circles (or rings), whereby each ring is served by a specific transformer that services the transmission lines for a particular ring.

The total cost of the project was estimated to be USD 21M. A large proportion of this went into investments into transmission lines, transformers substation and load dispatching between the main grids. Cost recovery was largely achieved by an indirect agricultural taxation through procurement of 'controlled' crops such as cotton, wheat and mung beans at below the crop export or import prices. Since groundwater development has a low capital investment per unit area overall, but relatively high O&M costs, the key economic issue is how to ensure that there are sufficient funds available to sustain the project works. Water charges have been introduced to cover the O&M costs associate with power, routine maintenance and repairs (World Bank, 1994). Nowadays, farmers across the scheme universally pay a fee for irrigation water of 9000 Kyat per acre for wet paddy and 6000 Kyat per acre for dry paddy. For other crops for all seasons the charge is 3000 Kyat per acre through a Water User Group (WUG). Production from the scheme in terms of total area planted over the period from 1995 to 2013 is 28% wet season paddy, 1% summer paddy and 71% non-paddy crops (Water Resources Utilization Department, Monywa, unpublished data).

Local WRUD representatives quote the cost of single tube well to be 5M Kyat. The cost of the turbine pump and electrical control system is 15M Kyat. Cost of the distribution system is 30M Kyat. Electrical consumption from the turbine pump is 18.5 kW per hour to supply 2400 m^3d^{-1}. The system is designed for pumping of around 14 hours per day but currently pumps can be operated for longer to meet water demands. Regular power shortages and poor reliability due to overloads on the grid system create significant problems with delivery across the command areas.

The irrigation well visited on electric circle 4 (no. 4/1) commands an area of 30 ha although around 25 ha is effectively under command (type 2 irrigation supplies the remaining command) (Figure A3.2). The system comprises a 46m deep well with 10-inch casing with screen over two productive intervals, pump delivering water to a main channel running along the upstream boundary which drains into 13 laterals which are traversed by 8 minor canals; the 13x8 grid arrangement supports 104 individual plots. The target aquifers are at depths of around 12-18 and 37-40m. The well yield is around 2400m^3d^{-1}. An aquifer pump test was first conducted to assess the long term yield and to size the command area. The double cropping system comprises of paddy for the wet season crop followed by wheat, chickpea or onion for the second crop. The estimated crop water demand is 1200mm for paddy and 600 mm for other crops.

The aquifers targeted include an upper layer at 12-18m of unconsolidated brown/yellow sands (Alluvial formation) overlying a lower layer of unconsolidated 'blue sands' of the Irrawaydian formation at 37-40m. Both aquifers are under pressure. A superficial low productivity aquifer is also present but is not targeted for commercial operations. The detailed project report by WRUD, (2005) indicates that the quality of the pumped water at the time of construction was fresh (120 μScm^{-1}) – other irrigation wells are more brackish at around 800 to 2400 μScm^{-1}. When classified for irrigation, the groundwater presents a moderate salinity hazard and a low sodium hazard but considered generally suitable for irrigation. However, the high salinity of water necessitated the provision of drainage works under the project.

All of the famers who use the scheme are smallholders with holding ranging in size from <0.2 ha or less through to >2 ha. Irrigation plans are developed through a committee comprising the famers WUG and government representatives taking into account the projected water and energy availability. At the tail-end of the command visited two private wells were in operation due to local supply shortfalls.

When the project started there were 157 wells constructed and over time 16 wells (10%) have been abandoned because the formation in these areas was unstable and extraction of fine sediments with extraction caused collapse of the screen. Since implementation, around 15 Italian (FIMNET) manufactured turbine pumps have been replaced with Indian (KSB) submersible pumps.

Sustainability reacted concerns were considered in the design of the scheme, and whilst accurate estimates of water balance for the project area were not available crude estimates of sustainable well-field capacity of 0.18 m was derived from hydrogeological investigations, which included the natural discharge of groundwater to the Chindwin River situated around 3km to the downstream. Monitoring well water level data from 16 wells suggest no deterioration although the duration of monitoring up until reporting was limited to only 2 years (GDC, 1984). The visit to irrigation wells suggested no major signs of over-exploitation, with the water levels in the shallow private wells that tap only the upper aquifer, visible at the soil surface whilst the pumps were active. Water level monitoring of the scheme had taken place in the past but has since been abandoned following the breakdown of equipment. Operational performance is gauged independently. WRUD would value the revival of the monitoring system for longer term planning that could address concerns about climate change and advanced warning about land subsidence.

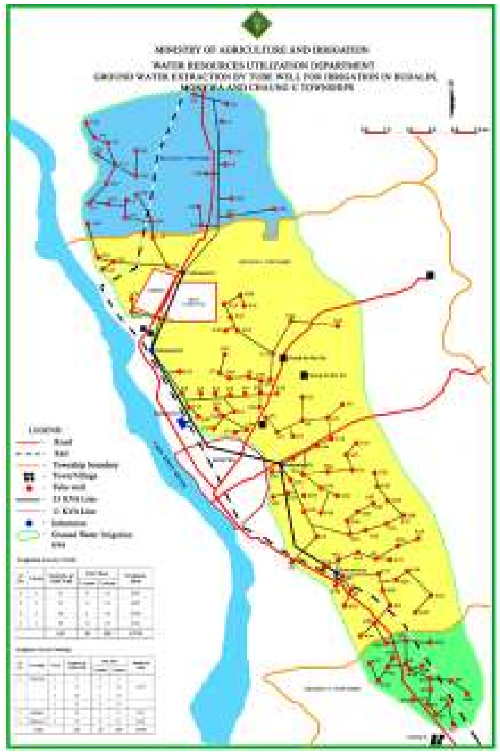


Figure A3.1. Current layout of irrigation wells for the Monywa groundwater irrigation scheme covering Monywa, Chaung U and Budalin Townships (Source: MOAI)

Figure A3.2. Pumphouse for community irrigation well 4/1 (the stilling tank before distribution is evident to the left of the image)

2. Tail-end farmers at Monywa (Type 2)

Type 2 operations can co-exist within a Type 1 system as in the case at Monywa where private farmers operate shallow tube wells at the tail-end of the system which have limited water availability, owing largely to constraints in power supply and pumping duration that are not able to serve the needs of all farmers within the command area.

Farmer owned tube wells are smaller in diameter and shallower than the community irrigation wells. They typically feature a smaller 3-inch casing and are screened over the interval from 12-18 m that taps only the upper brown/yellow sand layer aquifer (Figure A3.3). A 7.5 HP motorized pump supplies about $98m^3d^{-1}$. The cost of a well quoted to be 100,000 Kyat and the cost of the pump is also 100,00 Kyat. Fuel cost was reportedly 5000 Kyat. Urea was being applied at the time of the visit.

Figure A3.3. Tail-end farmer of Monywa scheme providing water from his well to the lateral canal

3. Water Trading and Co-investment at Nyaungkhan Village (Type 2)

Large portions within many of the large surface water irrigation project command boundaries are considered 'uncommadable' in the sense that the existing lift irrigation system cannot deliver water to those parts of the landscape. In these areas farmers are making investments in utilizing groundwater, sometimes in an innovative manner. In the Seik Nyaung Pump Irrigation Project, we visited Mr Aye Thaung, a farmer from Nyaungkhan Village, Taung Ther Township, who has gone into agreement and created viable informal irrigation through an entrepreneurial arrangement with three other famers situated on nearby lands. The well was constructed and paid for by another member of the village in 2007. The pump was purchased by Mr Aye Thaung. Two other farmers use the groundwater irrigation system to water their fields. This water trading and investment sharing initiative is self-started and free of formal agreements and based on mutual consent and willingness to participate. The owner of the well has 0.6 ha under irrigation at this site and two other farmers have 0.4 ha of land each bringing the total land under the command of the irrigation well to 1.8 ha. They pay a usage charge of 4,000 Kyat per day (not including the cost of the diesel) to the pump owner to use the well. The pump owner presumably shares this revenue with the well owner.

The irrigation well is 30m deep and was drilled by manual percussion methods (Figure A3.4). It cost 400,000 Kyat at the time. The 18 HP diesel pump used was bought 4 years ago for 450,000 kyat. The cost of a diesel gallon is 3,500 Kyat. On Mr Aye Thaung's land, family labour is used. He grows 0.4 ha of onions fringed with corn. The total input cost for this crop was 500,000 Kyat that covers costs of fertilizer (Inorganic fertilizer and cow dung are applied), pesticides and fuel. He will irrigate according to the plant water conditions as fuel is expensive. The crop requires 7 waterings over the life of the crop and each watering takes 11 hours. Eleven litres of fuel are used in the process. The discharge rate of the pump is 540 m^3d^{-1}.

The quality of water is slightly brackish and the sodium content is sufficiently high. This creates slaking of fine textured soil on the surface and problems with soil aeration, requiring seasonal rotation to allow the soil to remediate naturally. In the monsoon tobacco is grown. Whist onions fetch a higher price than tobacco, in recent times the price has become more unstable than tobacco. Growing an easily perishable crop and also because of lack of savings, most of the time Mr. Thaung similar to other typical farmers, is unable to wait for a good selling price. Mr Thaung owns 22.8 ha of land in total, including 0.8 ha for paddy within the commadable area which he irrigates with surface water.

Figure A3.4. Pumping into the distribution channel of the farmer who owns the pump set

4. New private well owner at Tanpinkan Village, Taungtha Township (Type 2)

Mr Shwe Myaing constructed a new well four months before our visit, after years of working with rainfed agriculture. He recently received a family inheritance, which he invested in improving the water management of his farm. A deep well was needed, because of the upland location of his farm, with a large diameter well to 6m and tube well to 55 m. The top few meters of the well are in limestone, but the most productive layer is the 'brown sands' found at depth. The total cost was 1.1 M kyat: 300,000 kyat for mechanical drilling of the well; 350,000 kyat for the down-hole pump; and 350,000 kyat for a large diesel engine, purchased second hand.

The well irrigates a field of 0.5 ha (Figure A3.5). For the first irrigated crop, onions were planted; when we visited, the crop was 1 month old. Land preparation took 1 month and cost 100,000 kyat. The soils are calcareous sands with low fertility, so cow dung and urea were applied. The expected yield from this harvest is 3000 Viss (4890kg). The selling price at present is 300-400 kyat per Viss.

Mr Shwe Myaing previously produced sesame and some mung beans under rainfed conditions; when the rains were good he was able to harvest 10 baskets (about 370kg) at most, but often the crop failed. Access to irrigation means that it would be possible to produce watermelon for export to China, with much higher potential returns. However, he chose to plant onions, like many other farmers in the area, citing lack of experience and high risk as the main constraints.

Figure A3.5. The newly constructed deep well pumping water that is manually spread across the first crop of onions

5. Recession farming Sin Te Wa River (Type 4)

Recession farming on the dry riverbed of the Sin Te Wa River is practiced during the pre-monsoon each year. Prior to the start of the dry season the concerned village committee distribute the available land and each farmer receives an allocation of 0.2 ha. Temporary holes are dug in the sand to a depth of a few tens of centimetres deep and sufficiently wide to accommodate direct access of the irrigator to fill containers and the sand walls of the hole are supported by bamboo reinforcing (Figure A3.6). Wells are quickly constructed within the matter if a few hours and are dug in grid-wise distribution to minimize the energy expended in water distribution. The water table is within close proximity to the surface and the irrigator typically uses dual watering cans to spread water to water a few square meters of crop per application. A minimal number of famers use small motorized pumps. The crop water demand in this treeless environment is high and the soil water storing capacity is low making frequent waterings a necessity. Irrigation commences in the cool of the early morning and by the middle of the day little activity is observed. The dominant crop is onions for the local market, although groundnut can also be observed in the fringe areas where the water table depth is sufficiently higher. The quality of water would appear to be good as onion is poor tolerance to salinity. White precipitates evident on the surface of the drainage canals would appear to be urea which as washed off from the plots and redeposited in concentrated form.

The farming practice is highly risky if the monsoon season begins earlier than normal (say in April or before), then the crop will be destroyed and the farmers will lose everything. In the most recent decade or so this has occurred in about one year in three.

Mr Shwe Myaing, the practicing Type 2 farmer described above, was until recently practicing Type 3 irrigation but came to be in a financial position to be able to invest in groundwater pumping infrastructure to undertake dry season irrigation of his upland site and primarily chose to do so because of the more assured harvest.

Figure A3.6. The entire Sin Te Wa River river bed is planted to onions during the dry season with regular grid of seasonal dug wells also evident

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Appendix 4: Current and past investments in water in the Dry Zone

Domestic and community water supply

Provision of safe water for communities is an important priority for both the Government of Myanmar and international donors and NGOs. Nationally, ESCAP et al (2011) reported that 71% of Myanmar's population had access to an improved water source in 2008, up from 57% in 1990. The IHLCA survey 2009-2010 estimated the proportion of the population with access to safe water (defined as being within 1 km of a private tap water, public tap or stand pipe, tube well, bore hole, protected hand dug well, protected spring / pond / rainwater) nationally as 69.4%: figures for the Dry Zone states, shown in Table A4.1, indicate that the Dry Zone has made significant improvements since 2005, so that only Magwe lags behind the national average. Shortages in the dry season are widespread: in a study of 630 households in the Dry Zone by WFP (2011), a total of 24% experienced shortages in the dry season.

Table A4.1 – access to safe drinking water (IHCLA 2010)

	2010					2005
% of population	Poor	Non-poor	Urban	Rural	Total	Total
Magwe	64.4	61.9	85.3	60.2	62.6	56.8
Mandalay	67.7	79.4	88.2	71.5	76.3	75.5
Sagaing	64.9	74.2	78.6	71.8	72.8	59.9
Myanmar	**62.2**	**71.9**	**81.4**	**65.2**	**69.4**	**62.6**

Rural water supply programs draw on a mixture of sources including shallow and deep tube wells, gravity flow systems, tapping dam systems, piped water supply systems, improved dug-wells, improved ponds and rain water collection tanks. The MICS 2010 survey (Table A4.2) indicates that in rural areas, about a third of people draw their drinking water from protected wells, and another third from tube wells, with only a small proportion (6.8%) using surface water sources. In many villages, multiple sources are used seasonally: while drinking water is primarily from wells, water for stock and washing is drawn from open ponds (in the wet season) or shallow wells (in the dry season). Village ponds often dry out in the early stages of the dry season and villagers will then revert to subsurface supplies that are more perennial in nature but may be quite remotely situated, so water must be carted in tanks for up to 3-4 km.

Responsibility for rural water supplies is shared between the Department of Development Affairs (DDA) in the Ministry of Progress of Border Areas, National Races and Development Affairs; the Environmental Sanitation Department under Ministry of Health; and the Water Resource Utilization Department (WRUD) of the Ministry for Agriculture and Irrigation (NCEA 2005). From 2000 – 2010, DDA has implemented a 10 year Project for Rural Water Supply by Development Committees of Sagaing, Magwe and Mandalay Divisions. JICA has provided assistance to this program under the project of Rural Water Supply Technology in the Central Dry Zone (JICA 2007), which aimed to construct and rehabilitate village tube wells, while strengthening the capacity of DDA in water supply technologies. In parallel with this initiative Bridge Asia Japan completed construction and rehabilitation of water facilities in 166 villages in Magwe and Mandalay in 2012.

Table A4.2 MICS survey 2010

Drinking water original data submitted to the JMP	pMICS10 Multiple Indicator Cluster Survey (Preliminary)	Myanmar 2010		
Generic classification	Original denomination	Urban	Rural	Total
Tap water: Total				
Tap water: Piped onto premises				
Tap water: Piped water into dwelling	Piped into dwelling	10.4	1.5	4.1
Tap water: Piped water to yard/plot	Piped into yard/ plot	9.7	1.7	4.1
Tap water: Public tap, standpipe	Public tap/ stand-pipe	4.8	5.3	5.2
Protected well or spring: Total				
Unprotected well or spring: Total				
Tubewell, borehole: Total	Tube-well/ bore-hole	30.2	32.0	31.5
Traditional well: Total				
Protected well: Total	Pro-tected well	16.7	31.7	27.2
Unprotected well: Total	Un-protected well	3.9	13.9	10.9
Protected spring: Total	Pro-tected spring	0.9	4.0	3.1
Unprotected spring: Total	Un-protected spring	0.1	1.3	0.9
Rainwater: Covered cistern/tank	Rain-water	0.6	0.7	0.7
Rainwater: Uncovered cistern/tank				
Bottled water: with other improved	Bottled water - with other improved	19.9	0.6	6.4
Bottled water: without other improved	Bottled water - without other improved	0.5	0.0	0.2
Surface water: Total	Surface water	1.0	6.8	5.1
River				
Pond				
Other improved source: Total				
Cart with small tank/drum	Cart with tank/ drum	0.8	0.4	0.5
Tanker truck provider	Tanker truck	0.4	0.0	0.1
Other non-improved: Other 1	Other	0.1	0.0	0.1
Other non-improved: Other 2				
DK/missing				
Total	Total	100.0	99.9	100.1
Calculations				
Estimations				
	Surface water	1.0	6.8	5.1
	Improved water sources :	93%	78%	82%
	Piped onto premises :	20%	3%	8%
Selections	Improved water sources :	Yes	Yes	
	Piped onto premises :	Yes	Yes	
	Surface water :	Yes	Yes	

WRUD also has responsibility for construction and operation of infrastructure for water supply in rural areas, and in 2013 reports 13,804 completed projects in Magwe – Mandalay – Sagaing (MMS) providing water for 6.86 million people (http://wrud.moai.gov.mm/)). This includes provision of piped and gravity-fed community water supplies, but the main focus is construction of groundwater wells for village use, with more than 13,700 wells, both deep and shallow, constructed to provide water for 6.65 million people.

UN agencies (including UNICEF, UNDP, UN-Habitat and WHO) have worked with the government on provision of water and sanitation in the Dry Zone since the 1970s, when a program was instituted to construct 3100 tube wells in MMS. Currently, the UN is supporting provision of water supplies to over 1700 villages in the Dry Zone, under the UNDP Human Development Initiative Integrated Community Development Program and the UN Human Settlements Program "Shae Tot" (MIMU WWW database, Nov 2012).

Non-government organisations, both local and international, are active in the water supply sector. MIMU WWW database lists 12 organisations (excluding UN agencies) active in the areas of safe water supply and construction and rehabilitation of water facilities in the Dry Zone in 2012, working in more than 465 villages. Projects cover a range of approaches to water provision, including deep tubewells for drinking water (eg JICA, Bridge Asia Japan); construction and renovation of multi-use village ponds (ADRA, Proximity, ActionAid and others); piped village water supplies and rainwater collection tanks (ADRA); affordable pumping technologies (Proximity).

Outcomes / lessons learnt

While recent progress has been impressive, the fact remains that more than 1 in 4 people in the Dry Zone do not have access to a secure source of safe water. Lessons from past programs :

- JICA (2010) found that many existing rural water supply tube wells were in poor condition or not functioning. They attribute this in part to poor siting and construction, and in part to lack of trained engineers for operation and maintenance.
- Because hydrogeology of the area is not well characterised, siting of wells in large part exploratory; yield and water quality cannot be assured before drilling
- The high cost of wells can drive communities to seek alternative lower cost supplies. JICA, (2010) give the example of Mingan village, where villagers opted for the construction of a primary school with roof rainwater collection facility instead of a deep tube well.
- Maintenance and desilting of ponds at least every 2-3 is critical to maintain viable volumes. NGOs working in the Dry Zone have reported that regular maintenance is often neglected, which means that more expensive and difficult renovation is then needed.
- Improving access to water (as well as availability) through piped systems, improved access points and pumping for ponds (Proximity, ActionAid).

A critical lesson from current programs is the importance of embedding water into broader village livelihood strategies, taking account of the full range of needs and users. ActionAid and ADRA have developed participatory methods for working with communities to ensure that water interventions are closely linked into village development plans, with clear delineation of responsibilities for construction, operation and maintenance.

Water for agriculture

Responsibility for agricultural water supply lies with the Ministry of Agriculture and Irrigation (MOIA), split between the Irrigation Department, responsible for surface water storages (dams and weirs) and large canal command gravity fed irrigation schemes; and the Water Resources Utilisation Department (WRUD), with responsibility for pumped irrigation projects (PIP), groundwater irrigation and spate irrigation systems.

The Government of Myanmar has prioritized irrigation development since the 1980s, with a major program of construction and irrigation development. In 2000, the government set a national target to make irrigation available for 25% of agricultural land (MOAI 2010), with an emphasis on provision of irrigation for summer paddy. MOAI identified five priorities for irrigation development: construction of new reservoirs and dams; renovation of existing reservoirs for raising storage capacity and efficient delivery of irrigation water; diversion of water from streams and rivulets during high water levels into adjacent ponds or depressions and for storage with sluice gates; lifting of water from rivers and streams through pump irrigation; and the efficient utilization of ground water (http://www.moai.gov.mm/). Estimates of total irrigated area in the Dry Zone (and nationally) vary very widely. Table A4.1 summarizes estimates from different sources.

Irrigation Department – canal / storage irrigation

The Irrigation Department reports 89 irrigation schemes in MMS based on storage in dams or weirs, with a total command area of about 344,257 ha (ID data, provided to IWMI 2013). These schemes are mostly gravity fed, from a network of canals and include major schemes (>10,000 ha) at Natmauk, Kyiohn-kyiwa, Mann Caung and Salin in Magwe; Kinde and Sinthe in Mandalay; and Ye-U in Sagaing, downstream of the Thaphanseik dam. The Irrigation Department works include storage dams, weirs, barrages, sluice gates, and canals for both irrigation and drainage, as well as flood protection works in some areas (MOAI 2010).

WRUD - Pumped Irrigation Schemes

WRUD is responsible for irrigation schemes without formal storage, including pumped irrigation projects (PIP) drawing on rivers; spate irrigation and small-scale water harvesting. Over 1000 small scale irrigation works were completed in the Dry Zone during the 1980s; a review in January 2013 indicated that rehabilitation work is required in many of these for them to function effectively. Since 2000, there has been a focus on developing large pump irrigation projects (PIPs) with command areas over 1000 acres (400ha), using high discharge pumps. WRUD has implemented 18 "Special Project" schemes totalling over 71,000 ha in MMS; another 7 projects with total command area of almost 50,000 ha are planned or under construction. Aside from the large "Special Projects", WRUD lists at total of 165 smaller schemes with an irrigable area of 67,000 ha completed; and 9 (5800 ha) planned or under construction. Six spate irrigation projects were implemented in the Dry Zone as part of UNDP HDI ICDP in 2003-7, irrigating around 300 ha.

WRUD – groundwater for irrigation

The widespread use of groundwater for irrigation in Myanmar began in 1989, with pilot trials funded by UNDP and IDA at Monywa. The success of these trials resulted in development of large groundwater projects at Monywa (141 wells serving 8094 ha) and the 99 Ponds project Yinmabin, Sagaing (440 wells irrigating 3300 ha), which draws from artesian wells. Since 2008, WRUD in collaboration with FAO has conducted a program to supply 800 tube wells for over 4450 ha in Meiktila - Tharzi zone of Mandalay Region; and is conducting on-going drilling programs in artesian aquifers in Sagaing and Mandalay regions. WRUD currently reports 6167 tube wells in MMS, irrigating an area of almost 33,000 ha (http://wrud.moai.gov.mm/). The WRUD 30 year Master Plan for the Dry Zone proposes installation of 1181 wells to provide irrigation for an additional 65,900 acres (28125 ha). Private drilling and pumping from aquifers also occurs, though usually on a small scale. The extent of private groundwater development is not known.

Non-government sector – agricultural water

Prior to 2010, NGO involvement in agricultural water was very limited, with most effort going to village and community supplies (see above). The MIMU Who-What-Where (WWW) database lists no projects in the sub-sector "Agricultural water" for 2009, but by 2012, there were 5 separate projects under Agricultural Water. The majority (533) of the 599 villages targeted are under the UNDP HDI project. In general, agricultural water supply is approached by NGO and donors as a component of broadly based livelihood programs. HDI-IV Integrated Community Development Project (ICDP) and the Community Development for Remote Townships Project (CDRT) both follow an integrated approach, where water supply is one component of multi-sectoral community development. Similarly, the CSEVI Shae Thot program is providing assistance and resources to communities to contract local providers to build water infrastructure, as part of a broadly based program on health and food security. Swanyee and MHDO (working with the Consortium of Dutch NGOs) are local NGOs working on livelihoods, including water supply.

Lessons learnt

The performance of formal irrigation schemes has generally been sub-optimal. The actual area irrigated is much lower than nominal command area. 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"[1], and that some reservoirs and diversion dams could not supply water at all. The report recommended that inefficient schemes be abandoned.

Anderson Consulting for LIFT (2011, 2012) conducted a comprehensive review of the efficiency and effectiveness of PIPs in the Dry Zone and identified a large range of issues affecting performance, including system design, operation and maintenance issues, availability of power for pumping, and inappropriate siting and soils. Many of these problems, particularly relating to O&M, are common to gravity-fed systems as well. In addition to technical problems, profitability is hampered by a lack of flexibility (most systems are designed to grow rice under flood conditions, with little attention to drainage, and are insufficiently flexible for other crops); and 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 O&M. The problems with O&M are illustrated by the rather startling statistic on the WRUD website (http://wrud.moai.gov.mm/) , that of a total of 6436 positions allocated to WRUD nationally, only 2074 have been appointed; with the forlorn note that" 723 daily wage labourers are being employed because of insufficient staff strength". Village surveys and reports from other projects indicate the generally poor performance of Water User Groups in water allocation and operation of schemes.

Although groundwater supplies only a small proportion of Irrigation (around 5%), use is increasing more rapidly than for other sources. Much of this development is small-scale private investment,

[1] http://www.mmtimes.com/index.php/national-news/1055-committee-urges-action-on-failing-irrigation-projects.html

observed, for example, during field visits in Monywa. The extent of private groundwater development is not known.

Table A4.1: Irrigation schemes (storage / weir) estimated by different sources

Region	District	Irrigation Department		FAO (2005)	IWMI (2013)	JICA (2010)
		No. of schemes	ha	ha	ha	ha
Magwe	Magwe	13	35,561	36,360	10,861	20,358
	Minbu	4	71,640	74,668	44,759	55,053
	Thayet	5	12,570	3,571	5,873	20
	Pakokku	15	13,569	5,969	12,168	793
Mandalay	Kyaukse	4	85,655	96,594	6,321	46,237
	Myingyan	15	15,500	10,346	29,007	6,016
	Nyaung-U	1	81	41	6,833	0
	Yamethin	9	24,996	72,751	3,493	-
	Meiktila	5	5,775	71,216	10,763	34,854
Sagaing	Sagaing	2	1,417	15,418	34,089	7,187
	Shwebo	4	53,825	274,964	94,566	192,124
	Monywa	14	23,668	23,348	8,608	19,467
	TOTAL	**91**	**344,257**	**685,246**	**267,342**	**382,110**

Table A4.2: WRUD pumped irrigation schemes in MMS (http://wrud.moai.gov.mm/)

		Special Project		**Electric**		**Diesel**		**Total**	
		No of sites	Irrigable area (ha)	No of sites	Irrigable area (ha)	No of sites	Irrigable area (ha)	No of sites	Irrigable area (ha)
Sagaing	Completed	5	30,958	11	10,530	40	14,016	56	55,505
	Under construction	3	26,305	1	223	2	1,489	6	28,016
Magwe	Completed	4	13,355	24	18,335	23	3,157	51	34,846
	Under construction	2	5,261	2	647		-	4	5,908
Mandalay	Completed	9	27,195	23	12,436	44	8,693	76	48,324
	Under construction	2	18,211	3	2,732	1	728	6	21,671
	Total	25	121,284	64	44,902	110	28,084	199	194,270

Table A4.3: groundwater for irrigation in MMS (WRUD http://wrud.moai.gov.mm/)

	Deep Tube wells	**Shallow tube wells**	**Irrigable area (ha)**
Sagaing	880	1968	20999
Magwe	1298	-	4271
Mandalay	1346	675	7696
Total	**3524**	**2643**	**32966**
	6167		

Watershed management / land and water degradation

Watershed management programs in the Dry Zone have been initiated in three different (but related) contexts:

- Soil and water conservation programs at field scales to prevent erosion and loss of top soil, with related declines in soil fertility, water-holding capacity and crop yields (eg Kahan 1997)
- Soil conservation and tree planting projects in small catchments to protect village water supply dams and ponds from siltation and improve water quality
- Large scale catchment reforestation programs to protect infrastructure from impacts of sedimentation, including siltation of reservoirs and clogging of irrigation canals by sand

The main causes of land degradation in the Dry Zone include deforestation (due to agricultural expansion, commercial and illicit logging, and excessive cutting for charcoal and fuel wood), poor agricultural practices, overgrazing, and shifting cultivation, all of which are exacerbated by demographic pressures. Shifting cultivation is often cited as a major cause of deforestation; in 2002 the Forestry Department estimated that 22.8% of forested area in Myanmar was affected by shifting cultivation (MoF 2005). However, evidence both from Myanmar and elsewhere (eg Lao PDR, see Valentin et al 2008) indicates that it is shortening the period of fallow (usually due to population pressure) that causes problems, rather than shifting cultivation per se. Traditional *Taungya* methods, with sufficiently long rotations, can support the conservation of natural forest ecosystems and biodiversity much more effectively than plantation monocultures (Khin Htun 2003, BEWC 2011).

Myanmar has one of the highest rates of deforestation in the world, estimated at 0.45 – 1 million ha per year during the 1990s (BEWG 2011). Presently, less than 20% of the Dry Zone is under closed forest and deforestation is continuing at a rapid rate. It is estimated that annual deforestation rate is 4.07% in Magwe Division, 1.48% in Mandalay Division and 0.68% in Sagaing Division respectively (UNCCD 2005). Dry forests around the periphery of the Dry Zone are particularly under threat, with a high proportion of degraded forests (Leimgruber et al 2005; NFI 2007). This is due in large part to agricultural encroachment and intensification of shifting cultivation.

The problems of land degradation in the Dry Zone of Myanmar were recognized as early as the 1950s, when a Dry Zone rehabilitation project was initiated by the Agriculture and Rural Development Corporation (ARDC) in collaboration with the FD. This comprise tree planting in degraded lands. Watershed management activities are carried out primarily under the Forestry Department (FD). Under the UNDP HDI program, watershed management programs were instituted in the 1990s (Community Multi-purpose Fuelwood Woodlots; and Watershed Management for Three Critical Areas) to attempt to reduce the rate of deforestation and related erosion and degradation of land and water resources (Cools 1995). In 1995, Myanmar set a Forest Policy objective to increase the area of Reserved Forest (RF) & Protected Public Forest (PPF) to 30% of total land area by 2010. In 1994, the FD implemented a special "Greening Project" for the Nine Districts of the Arid Zone and in 1997 the Dry Zone Greening Department (DZGD) was instituted to establish forest plantations on degraded land, conserve the remaining natural forests, promote the use of fuelwood substitutes and develop water resources (UNCCD 2005). DZGD proposed an integrated plan for 30 years 2001-2031 covering land utilization, soil conservation, water resource management, formation of forest plantation, natural forest management, training, research and extension, utilization of fuelwood substitutes, institutions and infrastructure development, policy and legislation. In 2002, the FD began implementation of a Watershed Management Plan to protect the catchment areas of 52 newly constructed dams, including those in the Dry Zone. The program covers about two million hectares, of which 75% are already degraded and 50% are in a critical condition.

Other agencies active in watershed management include the National Commission for Environmental Affairs (NCEA) under the Ministry of Forestry, which in 2002-5 compiled a National Action Plan to Combat Desertification under the UNCCD (MOF 2005). The Ministry of Agriculture and Irrigation and the Department for Progress of Border Area and National Race are involved in programs to decrease the incidence of shifting cultivation, through implementation of community based NRM activities.

The UN has been active in watershed management programs, through the UNDP HDI program; and the FAO programs on agricultural development and environmental management in the Dry Zone during the 1990s (Cools 1995; Carucci 1999) and local and international NGOs. Cools (1995) reported the use of a range of traditional SWC practices in the DZ (overflow bunds, gully plugging with rocks or crop residues, strip cropping, agroforestry techniques); other promising approaches include deep tillage, reduced tillage, zero tillage, mulching, planting basins and the use of crops with low water requirement. Kahan (1999) provides a detailed manual of SWC techniques specifically targeted for the DZ. Currently, FAO does not support programs in land and water management in Myanmar (FAO Field Programme Activities database online http://bit.ly/12hsA4v).

Forest Resource Environmental Development and Conservation Association (FREDA), Japan Overseas Forestry Consultants Association (JOFCA) and (JIFPRO) are cooperating with DZGD and FD in restoring degraded forest lands. Renewable Energy Association Myanmar (REAM) is working on renewable energy related services for rural development and environmental conservation in the areas of fuelwood substitution and biogas utilization.

Lessons learnt

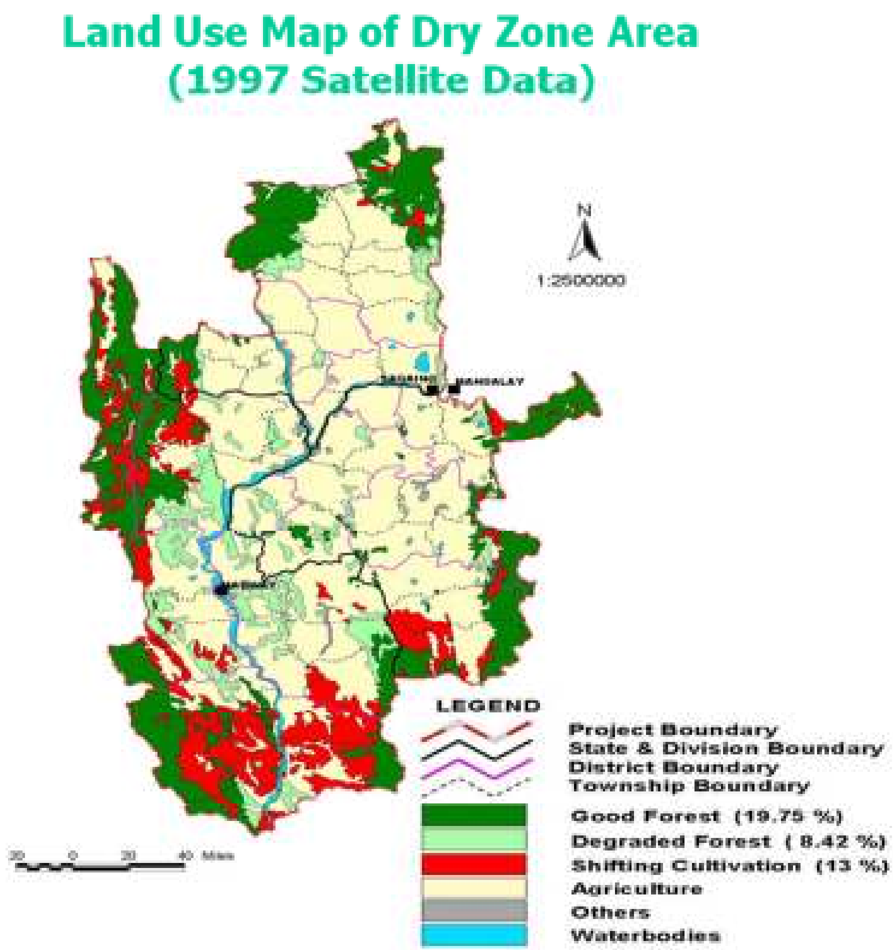
Cools (1995) demonstrated the positive economic returns from SWC measures in the Dry Zone at farm level. He noted that farmers in the region have traditionally invested in a range of SWC measures, but as farm sizes have decreased, low incomes and lack of savings have meant that for many farmers, funds are not available for SWC. He concluded that external financial resources are needed to implement SWC works on any significant scale. Landless and poor farmers could benefit from employment in such schemes.

A review of Community Forest Programs in Myanmar found that their performance was adequate but sub-optimal in terms of both forest regeneration and improving livelihoods; and that sustainability, particularly in the case studies in Mandalay Region, was problematic (Kway Tint et al 2011).

Dry forests around periphery of the Dry Zone are particularly under threat from deforestation and agricultural encroachment. Karin Luke (WHH) observed that in upland areas of Pauk, degradation is at critical levels, with widespread gullying, loss of topsoil and changes in river morphology due to large volumes of sand, which also clog irrigation canals, making them unusable. She concluded that community forest conservation and agroforestry projects had had a measure of success, but these are at small scale, and there is an urgent need to scale up to regional or national level, since degradation is beyond the level where it can be tackled by small projects.

Despite some major programs in watershed management, and a proposed DGDZ integrated plan for 30 years 2001-2031 covering forest conservation and land management, it is not clear either that the programs have been effectively implemented, or that there has been a significant change in rates of degradation.

Figure A4.1 Land use map of the Dry Zone based on satellite data from 1997 (from NFI 2007)



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Appendix 5: Piloting the 'Golongan system' in the Dry Zone

Water delivery schedule is defined by taking into account the relationship between water availability, total irrigated area, and different stages of crop growth. At present, water delivery schedule in irrigated area is defined primarily based on water availability linked to the total amount of irrigated area (and to a certain extent electricity supply for pumping). Technically, if water is available, total irrigation water discharge corresponds to the total irrigated area. In time of water scarcity, however, total available discharge might not be able to irrigate the entire command area with the required amounts of water. In irrigation management literature, scholars and practitioners have introduced various ways to rotate water supply (in terms of irrigation turns and duration) to cope with water scarcity issue. Nevertheless, effective rotation depends on existing technical infrastructure as well as local institutions' (WUAs, or other form of local institutions) ability to implement and enforce the defined water distribution rules. As illustrated in our case study, unequal water distribution in time of water scarcity often results in crop failures, conflicts among farmers in general, and between head and tail-end farmers in particular. Lacking any clear and transparent institutional arrangements, the water management committee and WRUD were unable to regulate and coordinate farmer's water taking activities.

Linking water delivery schedule with cropping calendar (cropping pattern), we can then divide farmers' fields into different groups so-called 'golongan'. 'Golongan system' (Gruyter, 1933; Pasandaran, 2010) as a rotation method was developed by Dutch engineers in Indonesia, as early as in 1933 and is still effectively applied in modern day Indonesian irrigation during drought management. Golongan system has two functions: 1) as a cropping system plan, aiming at continuous provision of land for certain types of crops, therefore ensuring the level of crops production; and 2) as a water distribution plan, aiming for efficient and fair distribution of water.

Golongan system refers to the staggering of planting dates successively among sections of irrigation systems, early in the planting season. As part of the arrangements, each group of farmers' fields (grouped by irrigation canal) will start their cultivation in a specified period, with 2 weeks time duration between the first and the second, and between the second and the third group. In this way, we do not only reduce the irrigation peak water and labour demands, but we also reduce institutional requirements to control and monitor the rotation schedule. As farmers would only take water when their crops need it, farmers who started their cultivation later would not take water before other farmers who started their cultivation earlier. In addition, the application of golongan system would also reduce operation losses, in terms of acquiring minimum level of water storage in irrigation canals, and reducing pumping frequency.

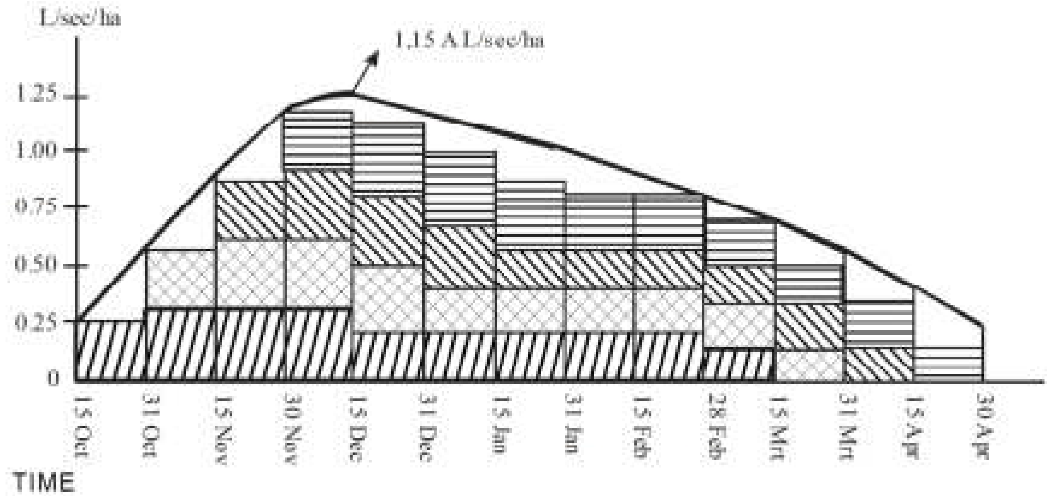

Figure A5.1: Water allocation over time in golongan system

Source: van Maanen (1931)

Figure A5.1 gives an illustration of how the golongan system was visualized as a water distribution plan. Here, water was allocated successively among sections of irrigation system to meet relative demand of area irrigated of each section. The shades in this figure indicate water allocation to the different golongan. In the beginning of the season water is given only to the first golongan, then to the first and the second golongan, and later after the water is sufficient, it is given to all four golongan. While the group composition/distinction of farmers fields fall within one golongan remain the same, the first turn for irrigation water supply was rotated between the groups on annual basis.

Applying golongan system does not necessarily mean locking farmers to grow a certain type of crops for the entire cropping seasons. The system is rigid in terms of seasonal arrangement, meaning that once a group of farmers decided to grow a certain type of crops in the start of the planting season, they have to stick to this decision, at least for that particular season. For the next planting season, they can decide to grow another crop (i.e. rice, cassava) as long as they can come to common agreement with each other. Technically, farmers in different golongan can also grow different crops. In Indonesia, some farmers grow paddy and others sugarcane within one irrigation scheme. This requires a lot of technical fine-tuning, but technically it is possible.

While this approach sounds like a straightforward one, it is based on several assumptions. First, it can only be applied if farmers are cultivating the same crops (i.e. paddy) as each farmer fields group has to have similar crop water requirement. Second, farmers in the same golongan have to stick to the same cropping calendar. In practice, the application of golongan system also requires a lot of technical information on the technical characteristics of the irrigation systems, and how this affect the overall calculation in water delivery as to decide when to start with rotation schedule (i.e. at which level does an irrigation system switch from continuous to rotational water supply; what is the relevant ratio between supply and demand); the appropriate scale the rotation schedule can be applied (i.e. the total area of tertiary unit as both technical and organizational unit); and the link between farmers' fields and main system management.

To conclude, while golongan system provides an interesting entry point to improve water management practices in the Dry Zone of Myanmar, a lot more of empirical studies (both technical and institutional) need to be conducted before we can decide on the system's applicability in particular irrigation systems.