Improving water management in Myanmar's Dry Zone

for food security, livelihoods and health

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International Water Management Institute

This report is based on a rapid assessment conducted in 2013 by the International Water Management Institute (IWMI) in collaboration with National Engineering and Planning Services (NEPS), and Myanmar Marketing Research and Development (MMRD) Research Services.

Contributors

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This is a summary report based on the following three publications:

Report 1:

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Report 2:

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Cover photo by Matthew McCartney: Collecting water from a shallow dug well in the bed of the Sin Te Wa River in Myanmar's Dry Zone.

Please send enquiries and comments to iwmi@cgiar.org
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Contents

Main messages

Managing water variability is key to improving livelihoods in the Dry Zone

Variability in water resources and insufficient capacity to manage that variability lies behind much of the prevailing poverty and food insecurity in Myanmar's central Dry Zone. Lack of reliable access to water constrains livelihoods and the development of a vibrant agriculture sector. The poor and landless are particularly vulnerable to climate shocks, such as droughts and floods, and other extreme weather conditions. Experience in other developing agricultural economies indicates that water management is an important entry point to improving smallholder production. It reduces the risk of crop failure, facilitates cultivation of a second crop, and enables farmers to invest in improved crop varieties and fertilizers. For landless people, it improves opportunities for employment.

Reduced rainfall is making rainfed farming more difficult

Rainfall is highly variable at the onset of the wet season. This unpredictability, which is particularly high in the central part of the Dry Zone, impedes agricultural production by increasing the risk of drought at the beginning of the rainfed crop cycle. Farmers' difficulties are being compounded by lower than usual rainfall; historical records indicate that, in recent decades, there has been a significant reduction in the amount of rainfall received in northern parts of the Dry Zone in June.

Access to water is more limiting than availability

Surface water from rivers and storage reservoirs is plentiful, but sparse infrastructure and the high costs of pumping constrain people's access to it. Estimated volumes of water used in irrigation (~7,540 million cubic meters [Mm^3]y^{-1}) are small compared to runoff (~39,000 Mm^3y^{-1}) and less than 3% of the total flow of the major river, the Irrawaddy (~360,000 Mm^3y^{-1}). This suggests that there is potential to expand irrigation in the future.

Formal irrigation is underperforming

The Government of Myanmar has made considerable efforts to expand irrigation, using gravity-fed canal and reservoir schemes, river pumping, and groundwater systems. However, the performance of formal irrigation schemes has been suboptimal, and the actual area irrigated is much lower than the planned command area. This is attributed to a mix of issues, including inadequate funding; communities' limited technical capacity for operating and maintaining facilities; availability and cost of energy for pumped systems; and a lack of flexibility in water delivery and scheduling. The efficiency of existing irrigation

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schemes is very low; less than 5% of water abstracted is transpired by crops. There is, therefore, significant scope for improving irrigation efficiency and crop water productivity. Farmers need better agronomic advice to help them make the best use of irrigation water.

Rainfed agriculture remains the dominant livelihood

At present, 515,000 hectares (ha) (less than 16% of the cultivated land in the Dry Zone) has irrigation infrastructure in place, and the proportion of farmland actually irrigated is even lower. In 2000, the government set a national target to make irrigation available across 25% of cultivated land, with the emphasis on providing irrigation for summer paddy cultivation. Even if this target is achieved, rainfed agriculture will remain the primary livelihood for a large proportion of the rural population, including many of the country's poorest people. Increasing the productivity of rainfed agricultural systems will be key to achieving food security and increasing household wealth.

Groundwater is a critical but limited resource

Although information on groundwater is sparse, current data suggest that the Dry Zone has moderate levels of the resource, with annual local recharge estimated at 4,777 Mm^3y^{-1}. This is equivalent to about half of the current surface water storage and less than 2% of total surface water resources. We estimate that this is sufficient to irrigate a further 110,000 to 330,000 ha. While groundwater is extremely important for the Dry Zone, its utilization must be planned and developed carefully to ensure it is used sustainably over the long term. The level of investment needed to establish groundwater irrigation schemes is highly dependent on the local conditions. Therefore, hydrogeological investigations are crucial to ensure effective planning and financing.

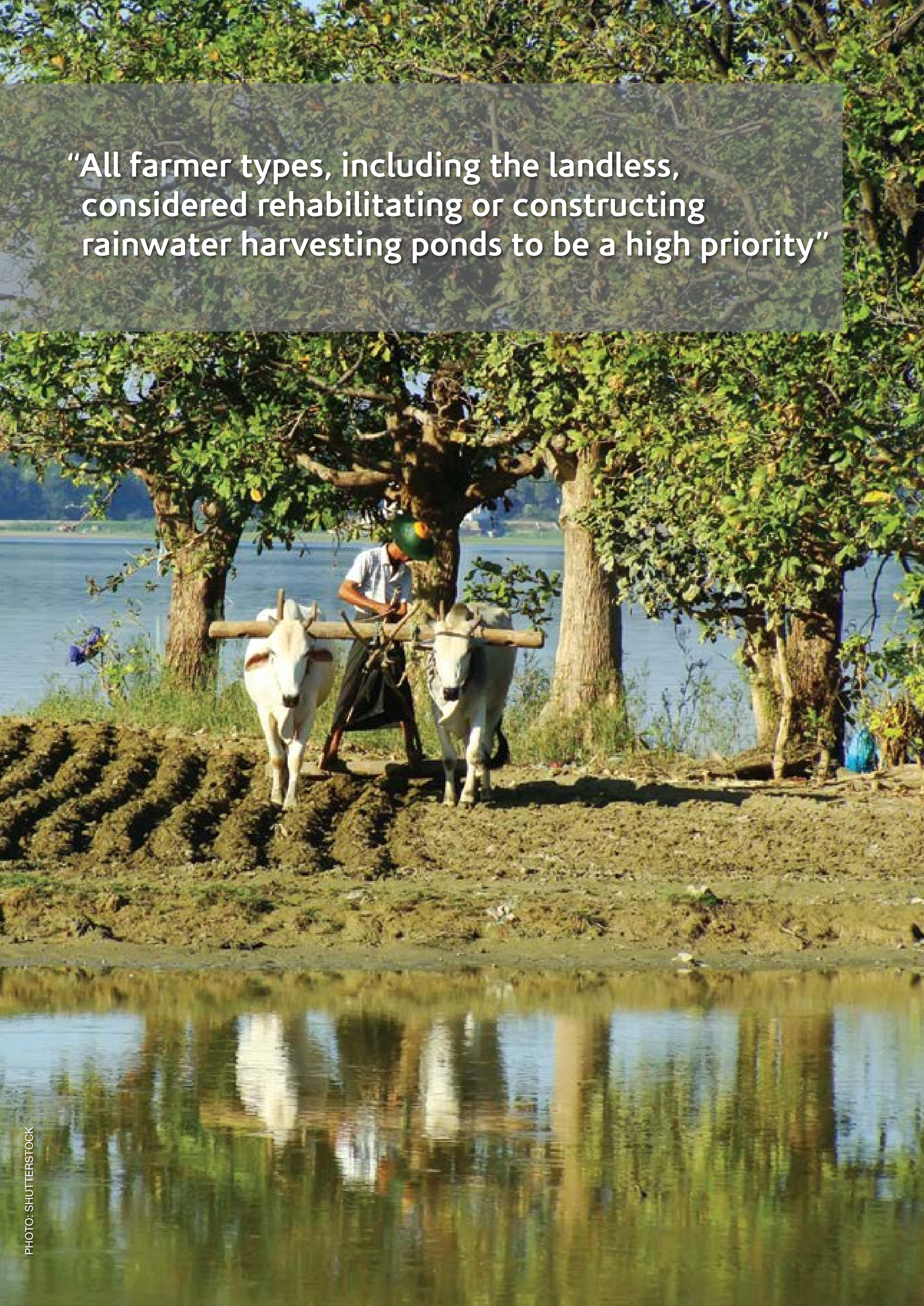
Farmers are using pumps to take water management into their own hands

Some farmers in the Dry Zone are adopting small-scale individual pumping of surface water and groundwater to overcome the vagaries of rainfall and shortfalls in existing formal irrigation schemes. They typically use small, motorized pumps to access water from shallow wells or streams. The best returns come from cultivating high-value crops. This can be an important means for farmers to improve their livelihoods, particularly during the dry season when alternative livelihood options are limited. Careful management and regulation of individual pumping is needed to prevent over-extraction of water resources.

Small-scale water management technologies can bring many benefits

Supporting small-scale agriculture is essential. Farmer-managed technologies, such as rainwater harvesting ponds and small-scale pumping, have significant advantages in terms of their flexibility, reliability, ease of use and simple maintenance. All villagers benefit from having assured access to water for domestic uses and livestock watering, while those without land gain opportunities to work within irrigated farming systems. Across Asia, small-scale agricultural water management technologies have been demonstrated to improve yields, reduce risks associated with climate variability and increase incomes. In many countries, water management by smallholders is overtaking the public irrigation sector, in terms of the number of farmers involved, the area covered and the value of production.

"All farmer types, including the landless, considered rehabilitating or constructing rainwater harvesting ponds to be a high priority"



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It is important to consider multiple uses of water when planning

A community-level qualitative survey, conducted in 24 villages, identified the water management approaches preferred by communities. All farmer types, including the landless, considered rehabilitating or constructing rainwater harvesting ponds to be a high priority, since these ponds provide access to water for drinking, other domestic uses and livestock watering. Landed and marginal farmers favored rehabilitating or extending existing irrigation infrastructure, but further investigations are needed to find ways of making these options more cost-effective. Groundwater wells were also popular options for many people. It is important that water interventions are embedded into broader village livelihood strategies and that they provide for multiple uses, rather than simply focusing on supplying water for irrigation. Priority should be given to interventions that will improve the livelihoods and well-being of the poorest people and those without land.

Simple solutions, but no single solution

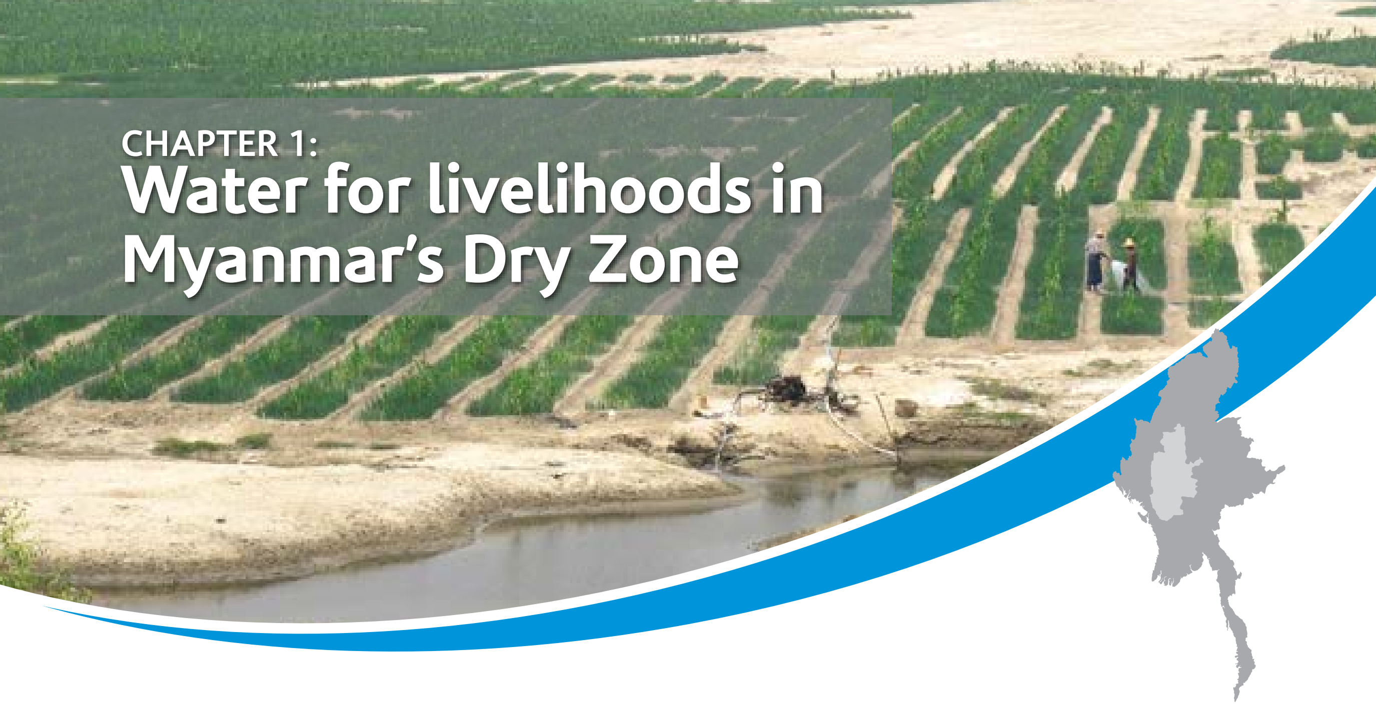
The Dry Zone's diversity of physical environments, farming systems, water access and irrigation infrastructure creates significantly different development opportunities and priorities between villages, even over quite small distances. A strategic water resources plan could avoid the largely piecemeal, non-sustainable development of water resources that has occurred in the past. Such a plan must recognize that there are no blanket solutions; rather, water-related interventions must be tailored to individual settlements. Local communities and agencies have a good understanding of the issues affecting particular villages and the potential solutions that could help to resolve those problems. The need is not so much for new technologies but for approaches that can refine, target and more effectively implement known technologies.

Priority investments

Studies conducted by the International Water Management Institute (IWMI) identified the following key methods to target investments in agricultural water management in the Dry Zone.

PHOTO: SONALI SENARATNA SELLAMUTTU/IWMI

- Review the water and energy productivity of existing irrigation schemes before undertaking major rehabilitation programs or constructing new schemes.
- Support sustainable development of groundwater using tube wells to secure village supplies and provide for small-scale supplementary irrigation.
- Invest in improved design and maintenance of small reservoirs for rainwater harvesting and storage.
- Promote soil and water conservation approaches to repair and revitalize degraded land; protect infrastructure from sediment damage; and manage water at field and watershed scales.
- Strengthen water resources planning and generate information that can guide future development.



CHAPTER 1: Water for livelihoods in Myanmar’s Dry Zone

About the study

In 2012-2013, the International Water Management Institute (IWMI), in collaboration with National Engineering and Planning Services (NEPS) and Myanmar Marketing Research and Development (MMRD) Research Services, undertook a rapid assessment on behalf of the Livelihoods and Food Security Trust (LIFT) to: (i) assess the water resources of Myanmar’s Dry Zone; (ii) evaluate key issues associated with water availability, access and management; and (iii) identify priority areas for investment in water management that would improve livelihoods and food security of the local communities. The study comprised three main components:

- An assessment of surface water and groundwater resources, considering availability, current uses, patterns, trends and variability at different spatial and temporal scales (Box 1).
- A community-level qualitative survey to evaluate issues of water availability, access and management for people with different livelihoods in 24 villages (Box 2).
- Analysis of existing irrigation programs, investment patterns and outcomes, including recommendations on where to prioritize future investments.

The study encompassed: (i) a review of existing information and published literature on water resources in the Dry Zone of Myanmar; (ii) meetings and interviews held with government agencies and development partners, including nongovernmental organizations (NGOs), with water-related programs in villages in the Dry Zone; and (iii) a village-based survey. Particular attention was given to evolving patterns of groundwater use for irrigation, in light of its increasing importance and concerns about sustainable use of the resource.

Myanmar’s central Dry Zone

The Dry Zone lies within Myanmar’s central plains, which are bounded by mountains to the east and west. Encompassing parts of Mandalay, Magway and Sagaing, it covers more than 75,000 km² and represents 13% of the country’s land area. The population of the Dry Zone is estimated to be around 10 million people, out of a total national population of 51.4 million (LIFT 2015; Department of Population 2014).

PHOTO: SONALI SENARATNA SELLAMUTTU/IWMI

Box 1: Assessing water resources of Myanmar's Dry Zone

Teams from IWMI and NEPS evaluated existing water resources, describing sources and availability of water, and the context in which decisions about water management are made. The research team obtained information, including hydrometeorological records, and data on groundwater availability, quality and use, from the Irrigation Department (ID), Water Resources Utilization Department (WRUD) of the Ministry of Agriculture and Irrigation (MOAI), and the Department of Meteorology and Hydrology (within the Ministry of Transport). Other data were sourced from publicly available regional and global datasets. Data are not consolidated centrally in Myanmar, and the way data are reported varies between agencies and regions. IWMI scientists analyzed the following:

- Spatial and temporal variability in rainfall patterns based on historical records and global synthetic datasets.
- River flows from (limited) records available at three gauging stations.
- Available water storage (based on government records of large and small reservoirs) compared to potential runoff (based on standardized rainfall-runoff relationships derived by MOAI).
- Irrigable areas based on estimates from MOAI and previous studies.
- Actual irrigated area in the dry season of 2012, based on high-resolution satellite imagery.
- Water volumes consumed in irrigation, using estimates of evapotranspiration (ET) derived from Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data.
- Groundwater availability and quality, and current rates of extraction based on government estimates and compilation of existing studies.
- Potential for groundwater development, based on comparison of estimated levels of extraction relative to recharge.

For more information, see McCartney et al. 2013.

Box 2: IWMI's community-level survey

IWMI and its national partners carried out a community-level qualitative survey in 24 villages across the three divisions of Mandalay, Magway and Sagaing. The research team undertook three mixed-gender focus group discussions in each village (a total of 72), at which three types of farmers were interviewed: (i) landed - those who owned between 5 and 15 acres[1] (2.0 and 6.1 ha) of farming land; (ii) marginal - those who owned less than 5 acres (2.0 ha) and were not food-secure throughout the year; and (iii) landless - those who neither owned nor rented land for farming and were not food-secure throughout the year. The aim of the focus group discussions was to gain a better understanding of the relationships between water-related issues and local livelihood strategies, especially for the marginal and landless farmers.

Villagers were asked about (i) the sources of water available to them; (ii) how they used that water (e.g., irrigation, livestock and domestic purposes); (iii) key constraints to availability and access, and how this affected their livelihood strategies and food security; (iv) coping strategies adopted by households and communities in the event of weather-related shocks, such as droughts; (v) perceived solutions and opportunities; (vi) interventions that had worked; (vii) lessons learned; and (viii) perspectives on priority measures and investments for the future. Institutional arrangements were examined at village or community level to identify how they related to farming strategies, water management practices and domestic water use. The focus group discussions highlighted a wide disparity between villages in terms of: (i) sources of water; (ii) availability of water spatially and through time; and (iii) how they were able to access water for different purposes.

For more information, see Senaratna Sellamuttu et al. 2013.

[1] 1 acre = 0.404686 hectares; 1 hectare = 2.47105 acres

The Dry Zone is mostly flat, with the Irrawaddy River (joined by the Chindwin River) flowing through it from north to south (Figure 1). The Bago Hills range runs parallel to the Irrawaddy River in the southern part of the Dry Zone, gaining altitude towards the north and ending in southeast Mandalay. Fertile alluvial soil is found along the banks of the major rivers, but the Bago Hills are sandstone and have less fertile sandy soil. As its name suggests, the Dry Zone is the driest region of the country, with annual rainfall between 500 and 1,000 mm.

Agricultural livelihoods dominate

Agriculture, primarily rainfed, provides livelihoods for a large proportion of the rural population, including many of the country's poorest people. According to JICA (2010), 58% of those living in the region are farmers and 25% are farm laborers. Similarly, other studies (World Bank 2012) also indicate that farming and casual labor in the agriculture sector are the two key livelihood activities in the Dry Zone. This evidence matches the findings of IWMI's community-level survey.

The distribution of cultivable land is highly skewed. Although estimates of landlessness differ widely, most available evidence suggests that approximately half of all rural households have no rights to use any cultivable land (Haggblade et al. 2013). They rely on casual labor to earn an income, primarily from agriculture or other activities, such as raising livestock. Pronounced seasonality of agricultural employment, a paucity of alternative jobs and low wages constrain annual earnings. Faced with lower incomes and higher poverty rates than land-owning families, landless households are more likely to go hungry and borrow money to purchase food. However, because land serves as collateral in informal lending, landless households typically have less access to credit than those that own land.

Food insecurity and malnutrition are very common in the Dry Zone. A survey conducted by LIFT (2013) found that 18% of households had inadequate food for consumption, and more than a quarter of children under the age of five were underweight. Households with poor access to land and markets, and those relying on casual labor, are the most likely to have insufficient food. Farming households are more likely to be food-secure, but food security is precarious even for these families. In 2010, the food security of 41% of farming households was adversely affected by dry spells (WFP 2011).

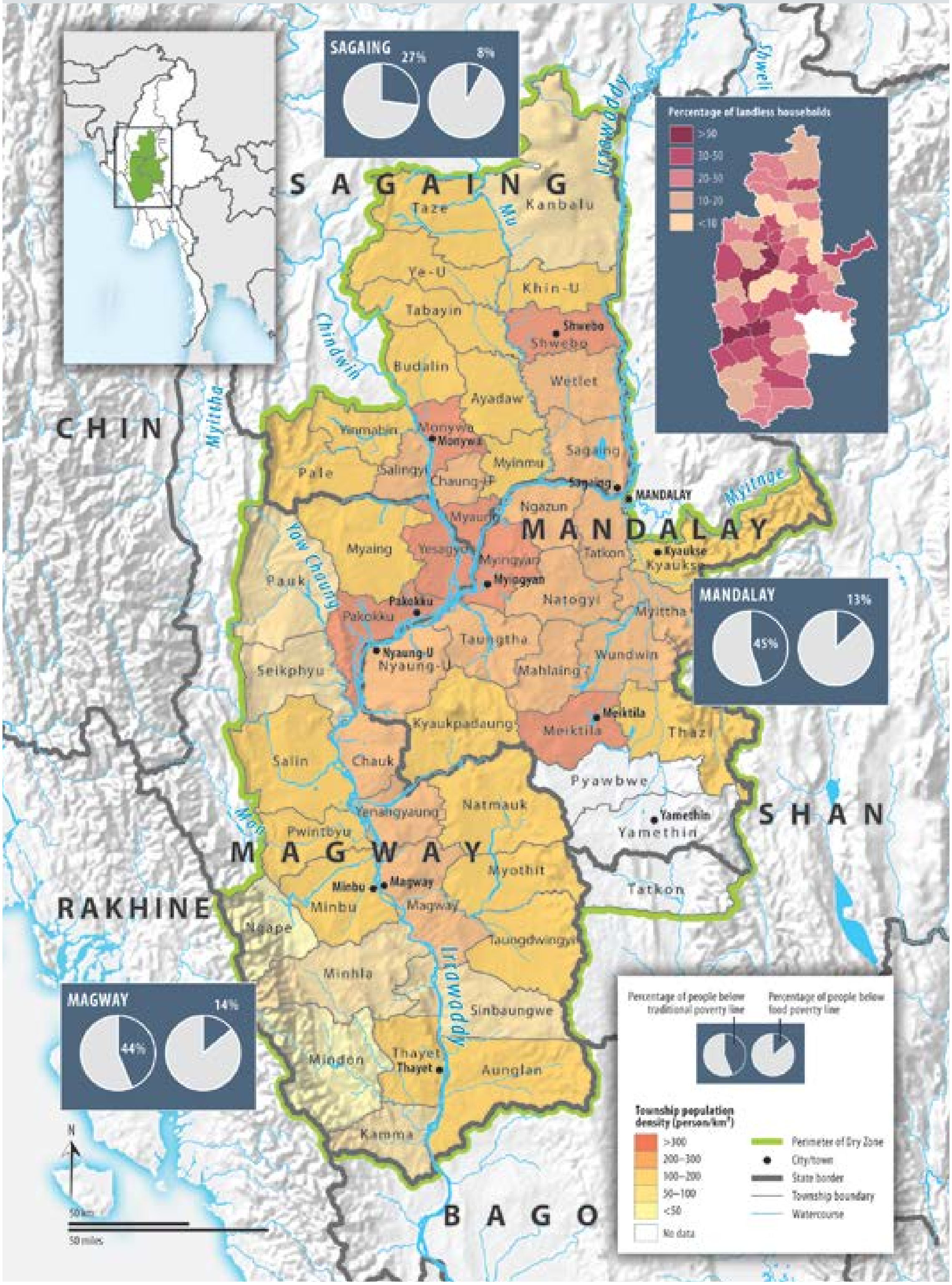
The experiences of other developing agricultural economies indicate that improving water management is an important first step to increasing smallholder production. Better water management reduces the risk of crop failure, allows for cultivation of a second crop, and enables farmers to invest in improved crop varieties and fertilizers. With less than 16% of the cultivated land presently irrigated, increasing the productivity of rainfed agricultural systems will be key to achieving food security, raising incomes and improving livelihoods.

Water for livelihoods

The Dry Zone is the most water-stressed region of the country. Around 70% of households have access to safe water for domestic use, which is close to the national average, but seasonal water scarcity is very common (MNPED and MOH 2011). A quarter of all households reported having insufficient water during the dry summer season (WFP 2011). About a third of people draw their drinking water from protected wells, and another third from tube wells. More than one-third of the population does not have access to sanitation facilities.

Access to water varies greatly between communities. Villagers derive water for farming and domestic use from a combination of sources, including rivers and streams, large and small reservoirs, village ponds and groundwater. Even within a single village, access to agricultural and domestic water can vary very widely.

Figure 1: The demographics of Myanmar's Dry Zone, showing the population density of townships and distribution of landless households. *(Source: Boundary/townships as defined by the Myanmar Information Management Unit [MIMU] [Map Id.: MIMU983V01], March 2013 [www.themimu.info/]; Statistics on population density, poverty and landless households from JICA 2010).*



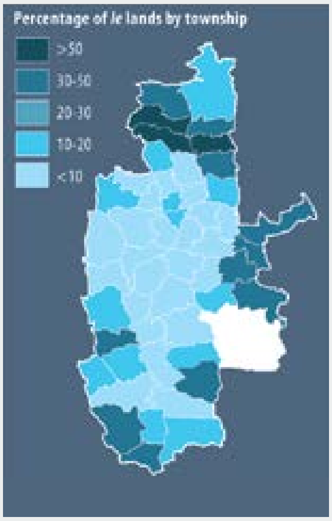
IWMI's community-level survey found that, of the water collected for use in villages (excluding irrigation), about 15-20% was allocated for drinking purposes, about 50% for other domestic uses and 30-40% for livestock watering. The relative proportions allocated between different uses did not appear to change significantly between seasons, during droughts or for the different types of farm households identified.

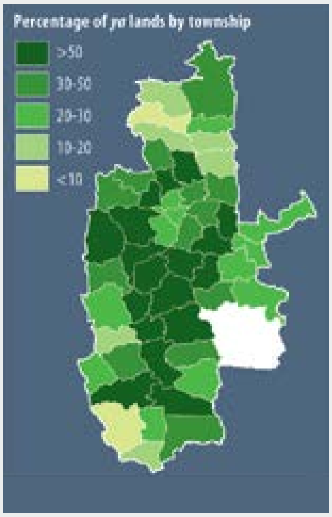
Agro-ecosystems of the Dry Zone

The Dry Zone's agricultural systems are complex; farmers cultivate paddy and non-rice crops (pulses, oilseeds, cotton, tobacco, vegetables and others), as well as raising large and small livestock (Figure 2). Traditionally, land in Myanmar is described in terms of its suitability for different types of cultivation, with the main distinction between *le* (paddy) and *ya* (dryland) lands (Box 3). The Dry Zone is vital to Myanmar's agriculture sector, producing most of the country's sesame, groundnuts and pulses (a major export earner), and 22% of its rice. Almost half of all the cattle, and more than two-thirds of all the sheep and goats in Myanmar are raised in the Dry Zone.

Box 3: Traditional land types in Myanmar's Dry Zone

***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* lands. Paddy is cultivated in the wet season, with a second crop of rice or other crops (oilseeds, pulses) also grown, depending on the availability of water.





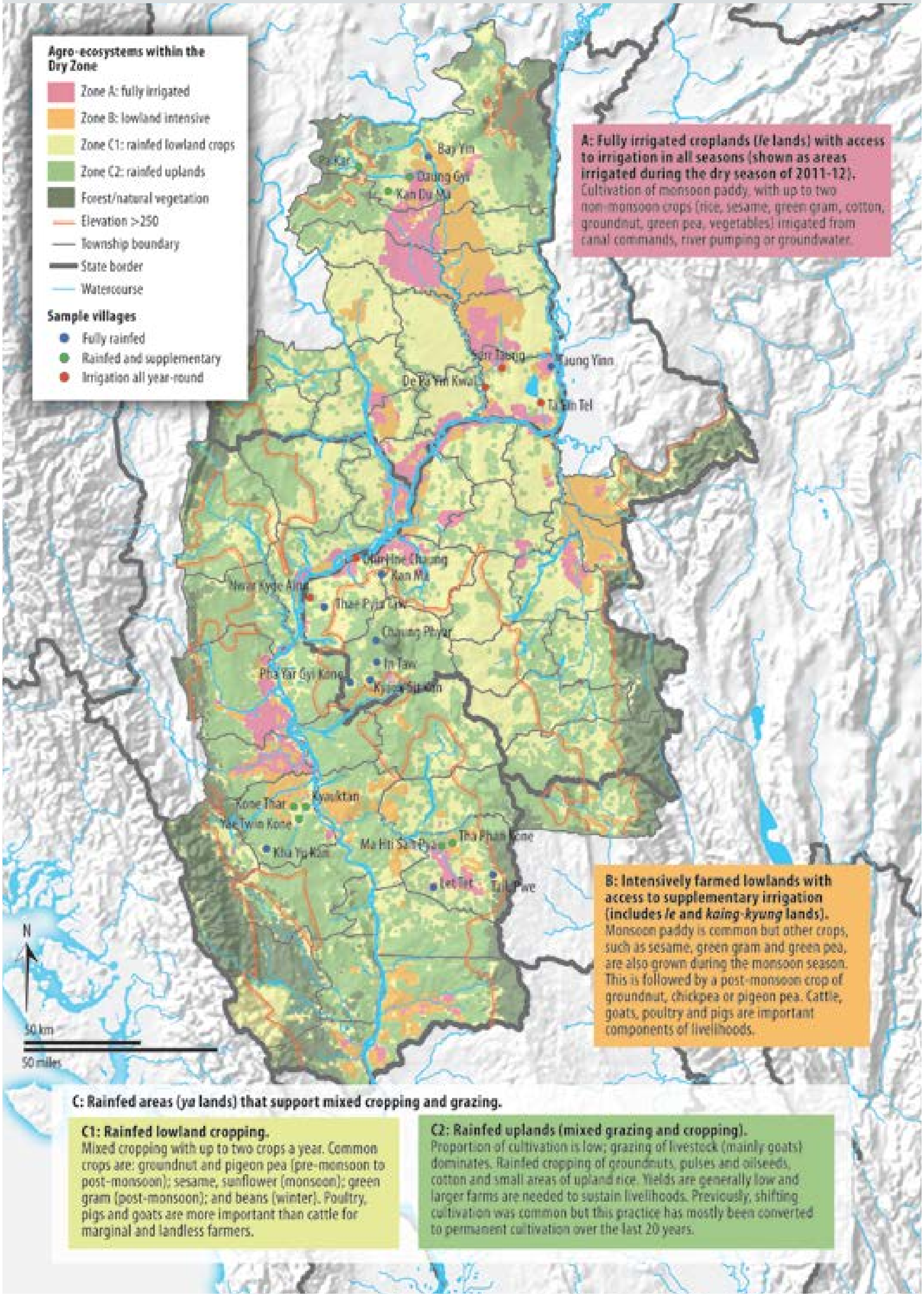
***Ya* (dryland):** Cropland not suitable for paddy cultivation. In the rainy season, farmers grow groundnut, sesame, sunflower and pulses.

***Kaing-kyung* (alluvial land/island):** Land near rivers, flooded during the rainy season, including areas within riverbeds. Soils are generally fine, sandy loams or loamy sands, and very fertile. Oilseeds, pulses, vegetables and tobacco are grown in the dry season.

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

Source: JICA 2010.

Figure 2: Map of the agro-ecosystems of Myanmar's Dry Zone, showing locations and water sources of the villages included in IWMI's community-level survey.

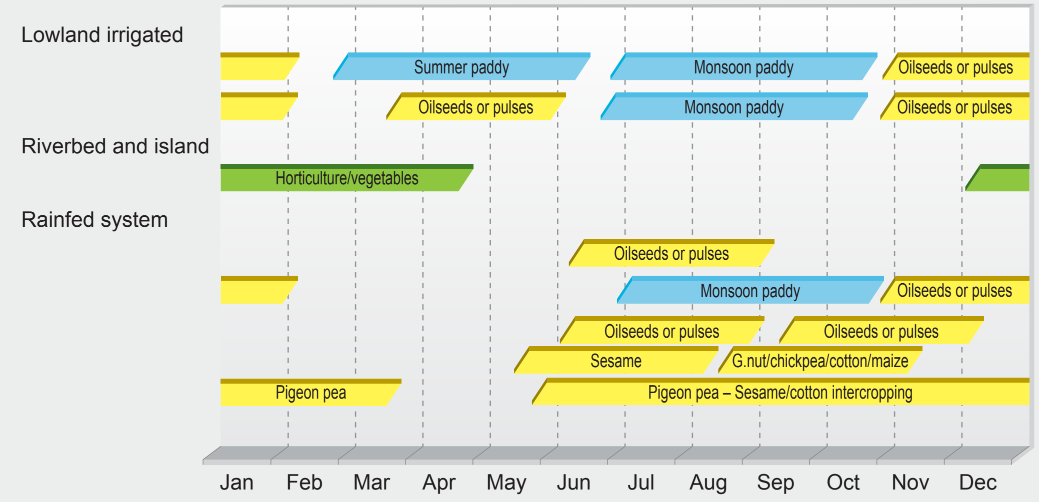


"Irrigation is used to secure the monsoon crop, protecting the plants from dry spells and low rainfall"

PHOTO: ISTOCKPHOTO

For the majority of farmers growing rainfed crops, decision making around planting is flexible, and the cropping calendar varies from year to year. On *le* and *ya* lands, farmers prepare the land between February and May. They then plant their monsoon crop between mid-May and mid-June, when soil moisture is considered to be sufficient. Pulses, such as green gram or chickpea, and oilseeds, such as sunflower, are cultivated until August or September. A second crop, such as groundnuts, chickpea or cotton, may follow, using residual soil moisture (Figure 3).

Figure 3. Sample cropping patterns in the Dry Zone *(Source: LIFT 2012; Note: G.nut = Groundnut).*



Irrigated areas with year-round access to water lie mainly within formal irrigation schemes. These include major schemes, such as those in Minbu, Kyaukse and Ye-U, and smaller schemes – pumped irrigation systems, in particular – along the Irrawaddy and Chindwin rivers. Irrigation is usually developed on *le* lands that have higher agricultural potential, although some schemes report problems with sandy soils. Small-scale groundwater irrigation is found in some areas, generally supporting small-scale horticulture, which provides a high financial return and is usually implemented by wealthier households.

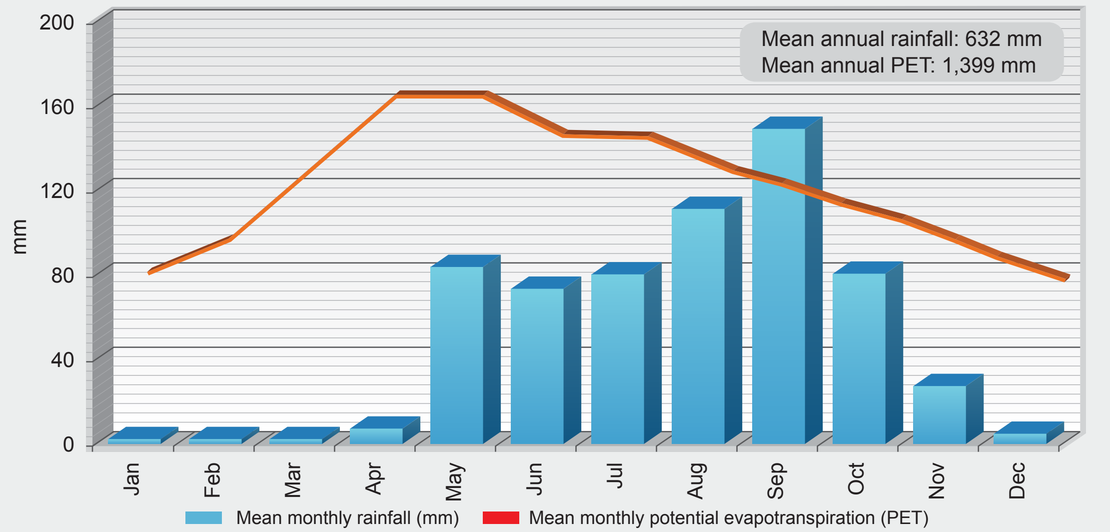
The farming calendar on irrigated landholdings includes a summer crop of paddy, which is fully irrigated from mid-February to May. Some farmers also plant a fast-growing crop, such as green gram or green pea, in early March or April for harvesting in May or June. This is followed by a primarily rainfed monsoon crop, such as paddy, which reaches maturity in October or November. Irrigation is used to secure the monsoon crop, protecting the plants from dry spells and low rainfall.

CHAPTER 2: Water resources of the Dry Zone

The influence of climate

Mean annual rainfall in the Dry Zone ranges from 500 to 1,000 mm. This is low compared to the 2,000-5,000 mm range received by the rest of the country (Figure 4). Temperatures commonly reach 40 °C in the dry season. The Dry Zone is the only truly semi-arid area of Southeast Asia; annually, rates of evaporation are more than double those of rainfall.[2] The wet season, coinciding with the southwest monsoon, lasts from May to October. The dry season is divided into winter (between November and February) and summer (from March to April).

Figure 4: Mean monthly rainfall and potential evapotranspiration (PET) at Pakokku, close to the center of Myanmar's Dry Zone *(Source: FAO LocClim: Local Climate Estimator [http://www.fao.org/nr/climpag/pub/en0201_en.asp]).*



[2] United Nations Environment Programme (UNEP) defines 'semi-arid areas' as having rainfall/potential evapotranspiration (PET) < 0.5.

PHOTO: SONALI SENARATNA SELLAMUTTU/IWMI

The Dry Zone is characterized by erratic rainfall. Rainfall patterns differ widely between neighboring districts and from year to year. There is a widespread perception that, over the last 20 years, the duration of the monsoon has reduced while rainfall events have become shorter but more intense. IWMI conducted a rigorous statistical analysis of past rainfall trends, using a 56-year record (1951-2007) from the APHRODITE[3] dataset (Yatagai et al. 2012) (see McCartney et al. 2013 for a detailed description of the methods used).

IWMI's analyses (as outlined in Chapter 1, Box 1) confirmed the high spatial and temporal variability of rainfall in the Dry Zone. The central area receives, on average, less than 500 mm of rainfall during the wet season and less than 600 mm per year, while the periphery receives up to 1,000 mm annually. Despite this, the dry season is relatively wetter in the center of the Dry Zone. This paradox arises because the wet season is shorter here, and more light rainfall events occur during the onset and retreat of the monsoon. It is too risky for farmers to try and use this rainfall to cultivate crops, as it comprises many light rainfall events interspersed with long dry periods.

The date on which the wet season begins each year is much more variable than the date on which it starts to retreat. This presents a major challenge for those farmers who rely exclusively on rainfall for water. Dry spells within the wet season are particularly long in the center of the Dry Zone. The longest dry periods, of up to 14 days, generally occur in late July or early August.

In recent decades, in northern parts of the Dry Zone, there has been a statistically significant[4] decline in rainfall during June. It diminished by 50 mm (around half of the mean rainfall during June) over the period 1966-2002 (Figure 5). Combined with the very high variability in the onset date of the wet season, and its relatively short duration, this change has increased the risk of early drought at the beginning of the rainfed crop cycle. The central part of the Dry Zone is particularly vulnerable. Observations of weather patterns made by farmers largely tally with the scientific evidence (Box 4).

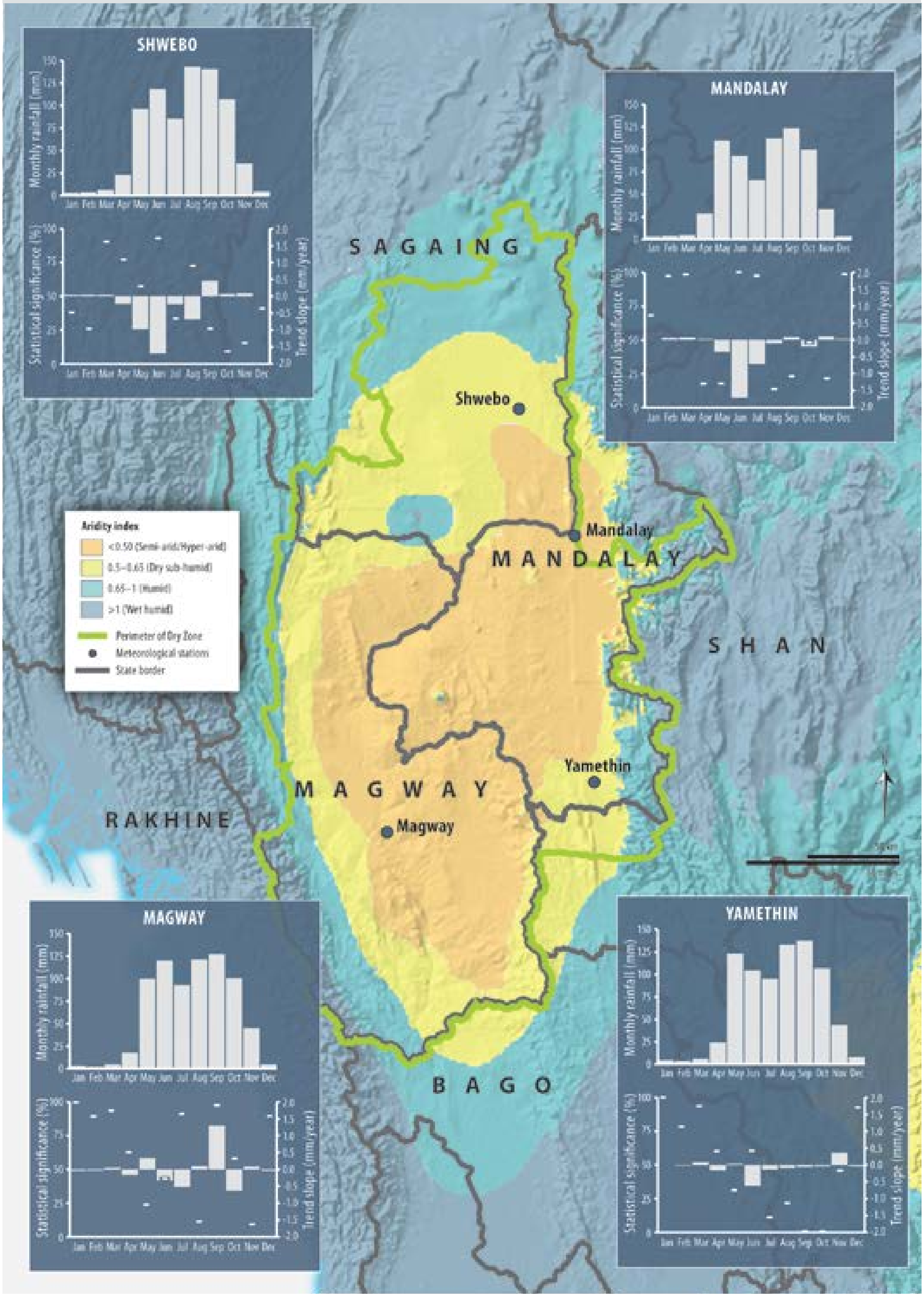
No statistically significant trends were found in the rainfall during the dry season, the start and end of the wet season, or the length of the longest dry spell during the wet season. However, the results confirm that relatively low and variable rainfall are key constraints to rainfed agriculture, particularly in the center of the Dry Zone.

PHOTO: ISTOCKPHOTO

Historical data on Myanmar's climate over the past 60 years indicate that temperatures have risen, on average, by 0.8 °C per decade. According to regional climate modelling, Myanmar is likely to experience a warmer climate in the future, with a longer summertime, heavier rainfall during the rainy season in some areas and higher annual precipitation overall. Additional climate change scenarios are needed to address the uncertainty of these long-term climate predictions (Han Swe 2014).

[3] Asian Precipitation—Highly Resolved Observational Data Integration Towards Evaluation of Water Resources
[4] Statistical significance > 90%.

Figure 5: **Mean monthly rainfall patterns at four locations, with the associated trend slope (grey bars) and statistical significance (dashes) computed for the period 1966-2002.**



Box 4: Impacts of climatic events on villagers

As part of IWMI's community-level survey, farmers were asked to recall extreme climatic events (such as droughts, floods and shifts in the timing of the monsoon) and to explain any impacts such events had had on their livelihoods. Their experiences are presented here.

Dry spells

The most frequent weather phenomenon reported by farmers was the 'dry spell' (defined as a short period without rainfall), which usually occurs around July during the early part of the monsoon. Of the 24 villages in the sample, 20 reported dry spells. Dry spells are normal during the monsoon. However, if they last for prolonged periods (i.e., more than 2 to 3 weeks), this can cause problems for farmers. During such times, in situations where community water sources are limited to rainwater collection or shallow wells, even access to water for domestic use can be affected. This was the case for Kha Ku Yan village in July 2012. Water for domestic use and livestock became severely limited; villagers reported that many animals died. In Kan Du Ma village, the weather turned dry after the first two rains of the year. Some farmers had to delay cultivating their crops; others suffered losses due to the lack of water after sowing.

Droughts

Droughts (defined as low rainfall for the entire season) were less frequent, with only three villages affected during the last decade. In 2004, a drought hit Ta Ein Tel village when the monsoon was late and rainfall lasted for only 2 months. Farmers could not cultivate rice paddy, wheat produced a low yield, and chickpeas could not be harvested. All types of farmers were affected, and households were compelled to obtain loans to invest in a post-monsoon winter crop or to purchase seeds with credit. In some cases, farmers sold their land and, where there was a lack of forage, also their cattle. Landless people suffered from a lack of access to forage areas for their livestock, and could not find employment opportunities in the village. Accessing drinking water was difficult; supplies had to be brought in by cart from outside the village.

Early retreat of the monsoon

Although the end of the monsoon is generally more predictable than the onset, it sometimes ends earlier than expected, leaving crops without water before they are ready for harvesting. In Taung Yinn village, respondents described an occasion when the monsoon ended at least 4 weeks earlier than usual. This affected the post-monsoon winter crop because there was less water available in the soil and the temperature was higher. Lower production led farmers to sell livestock or land to repay loans they had obtained to grow the crop. Unusually extensive infestation by pests increased farming costs. Meanwhile, casual labor opportunities were hard to find, compelling landless farmers to obtain loans or migrate seasonally to find employment.

Flooding

Floods often affect farmers' monsoon crops. Both paddy and dryland crops can be damaged, if flooding is sufficiently severe. This results in food insecurity and financial problems for households. In Taung Yinn village, some land was submerged for up to 7 weeks during one monsoon season and farmers could not cultivate their fields at this time. It particularly affected marginal farmers with limited access to other land. Landless farmers had to seek casual labor outside of the village.

Cyclone Giri

This powerful tropical cyclone struck Myanmar in October 2010. In Kan Ma village, it seriously damaged the main rainfed crop. Farmers sold their assets or obtained loans to support their households. Casual workers could not find any work locally and had to migrate. Livestock were affected, especially goats. In Thae Pyin Taw village, the storm severely damaged the second monsoon crop and affected the supply of forage for livestock. Household members migrated to the cities of Mandalay and Yangon to find work.

Surface water resources

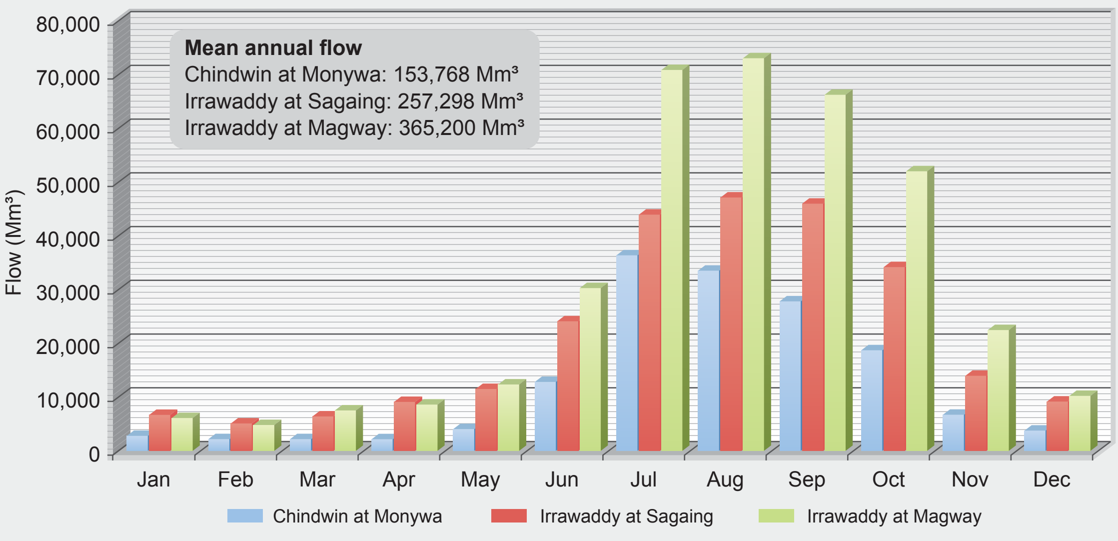
Rivers and runoff

The Irrawaddy River and its tributaries dominate surface water resources in the Dry Zone. The Chindwin River is the major tributary of the Irrawaddy River; other significant tributaries are the Mu, Shweli and Myitnge. These rivers provide water for irrigation and, in some places, recession agriculture, where farmers capitalize on natural flows and sediments to irrigate and fertilize crops on floodplains. However, some of the river courses are deeply incised into the landscape, so water for irrigation can only be obtained by pumping.

River flows are highly seasonal. The larger rivers flow all year-round, but many of the smaller streams are ephemeral. In some cases, when water levels fall below the level of the riverbed, flows continue in the sandy aquifers of the river channel, and can be accessed through shallow wells and sand dams. Cultivation in dry streambeds during the dry season is common, but carries a high risk of losing crops to early floods.

Water levels are measured at key locations in the Dry Zone during the wet season to provide flood-warning alerts, but few measurements are made during the dry season. Seasonal variation in water flow is very high: on average, around 85% of the flow in both the Irrawaddy and Chindwin rivers occurs during the wet season between May and October. The flow of the Irrawaddy River in February, the month with the lowest flow, is less than 2% of the total annual flow (Figure 6).

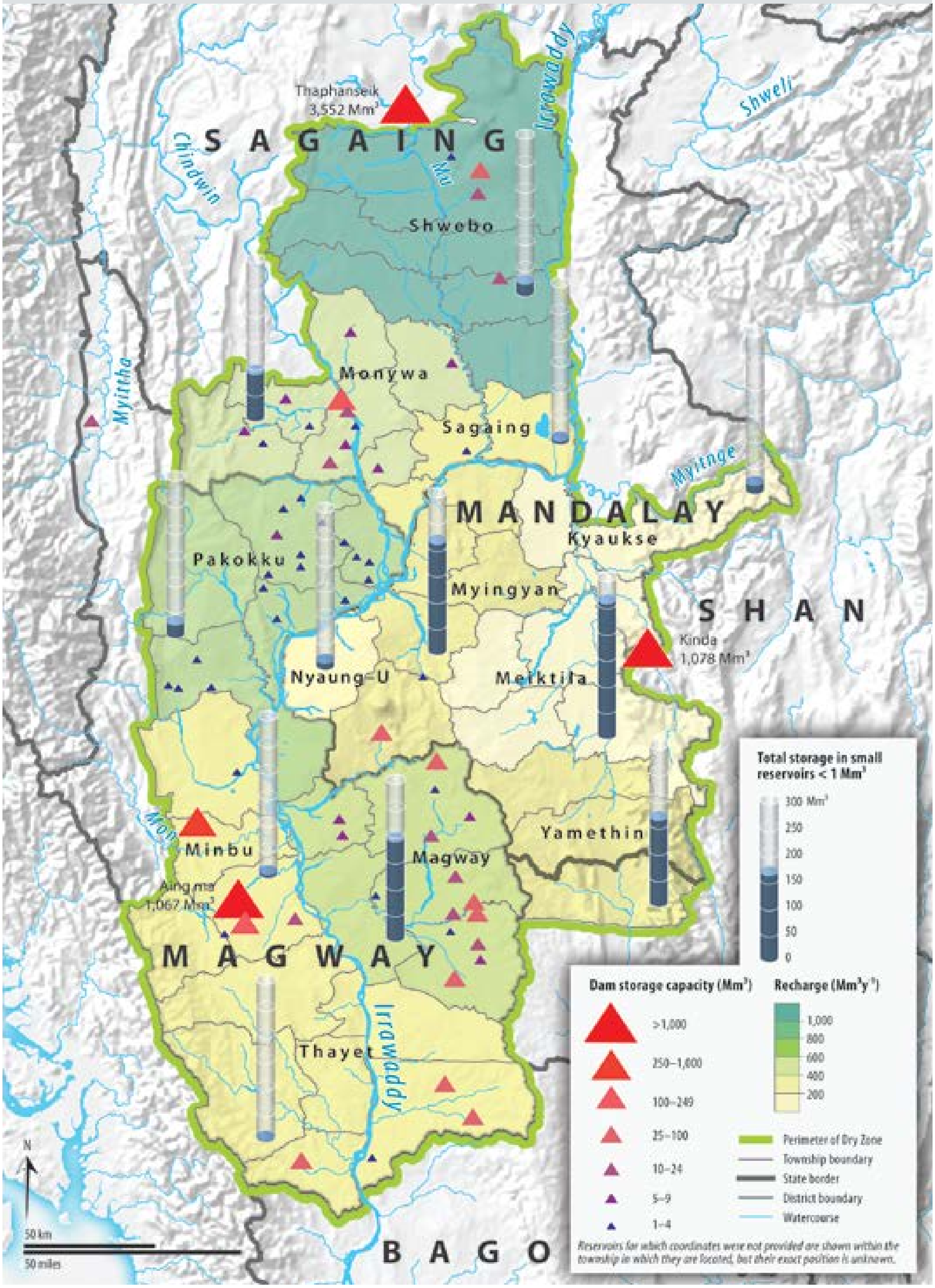
Figure 6: Mean monthly flow of the Chindwin River at Monywa, and the Irrawaddy River at Sagaing and Magway *(Source: derived from data provided by ID, Myanmar).*



Storage in large and small reservoirs

Given the seasonal nature of rainfall, communities need to retain and store rainwater and runoff received during the wet season for use in the dry season. In the Dry Zone, existing facilities for this range from large reservoirs, for irrigation schemes, to small village ponds. The Government of Myanmar has constructed more than 60 large reservoirs (> 1 Mm³), mainly within irrigation schemes (Figure 7). The total storage capacity of these large reservoirs is estimated to be 7,760 Mm³.

Figure 7: **The locations of large reservoirs (> 1 Mm³), total volume of water held in small reservoirs for each Dry Zone district, and the annual rate of groundwater recharge for each district** *(Source: Groundwater recharge figures from MOAI 2003).*



Runoff captured in small storage facilities (< 1 Mm^3) provides a valuable water source for villagers. At present, the total water storage capacity in approximately 2,000 small reservoirs is estimated to be 1,020 Mm^3. In the past 20 years, many small reservoirs, ponds and tanks have been constructed by MOAI to provide water for domestic use, small-scale irrigation and livestock. NGOs, including ActionAid, Adventist Development and Relief Agency (ADRA) and Proximity, have also worked to construct and rehabilitate many such structures. Rehabilitation is required, as small reservoirs in the Dry Zone are often prone to siltation and embankment failure.

Groundwater resources

The four major aquifer groups across the Dry Zone vary considerably in the quantity and quality of groundwater they yield (Figure 8). The Irrawaddy and Alluvial groups constitute the most important aquifers, supplying groundwater that is of sufficient quality for both domestic and irrigation use. Suitable resources are less common in areas underlain by Pegu and Eocene aquifers (Drury 1986).

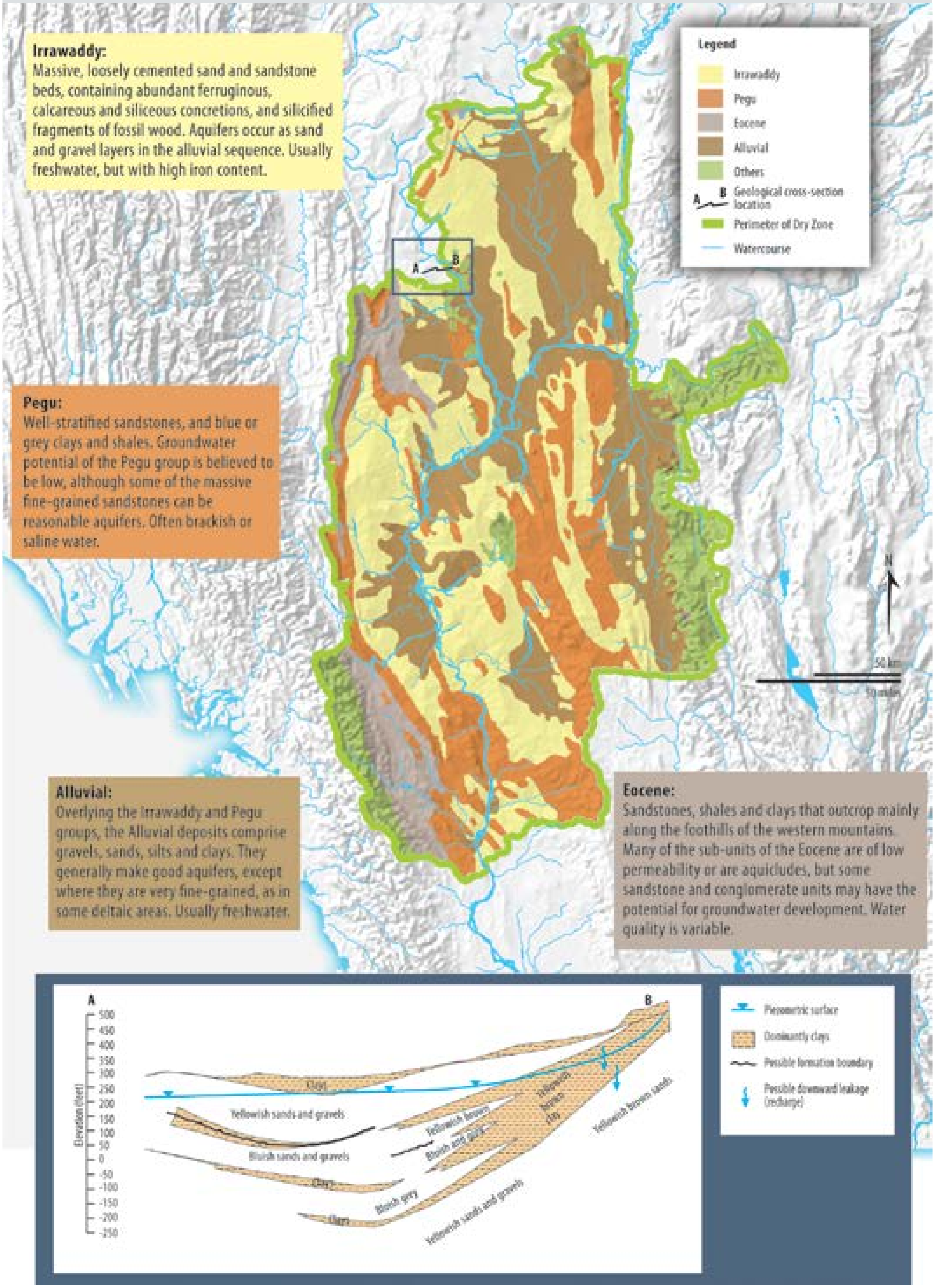
There is a widespread view that the groundwater reserves of the Dry Zone are vast and largely unexploited (e.g., ESCAP 1995). The Food and Agriculture Organization of the United Nations (FAO) estimated a groundwater potential of 150 km^3 for the Upper Irrawaddy and Chindwin river basins (Le Huu Ti and Facon 2004). However, the hydrogeology of the area is complex, and little is known about the recharge and transmission dynamics of the groundwater systems.

IWMI collated and analyzed data from MOAI on district-level estimates of rainfall-derived groundwater recharge. This data indicated annual recharge rates to be around 30 mm to 90 mm, giving a total annual recharge volume of 4,777 Mm^3 for the Dry Zone. Thus, the annual replenishable volume that can be safely used without diminishing the resource is around 2% of the total surface water resources and about 50% of the total surface water storage. This does not indicate great abundance; rather, it points to a moderate resource that must be planned and developed carefully to facilitate long-term use. Shallow alluvial aquifers situated adjacent to the rivers may be supplemented by recharge from seasonal high flows, but the magnitude and extent of this component of recharge must be evaluated.

Groundwater quality would appear to be fit for general purposes over large parts of the Dry Zone. It is generally of low to moderate salinity (typically 1,000 to 2,000 μScm^{-1}), although brackish to saline groundwater is found, in particular, in the Pegu aquifer in the western and central areas. High levels of iron and manganese in the water are commonly reported, but this does not usually constrain use. The extent of arsenic contamination in the Dry Zone is not well established. Data from WRUD, based on studies carried out between 1952 and 2013, indicate that around 80% of 30,000 samples from Mandalay, Magway and Sagaing have arsenic concentrations lower than the World Health Organization (WHO) drinking water guideline value of 10 μgl^{-1}. However, more than 100,000 people in the region could potentially be exposed to arsenic concentrations that exceed the level of 10 μgl^{-1}. Future projects to exploit groundwater must ensure that arsenic levels are acceptably low (Mr. Kyi Htut Win, WRUD, pers. comm.).


PHOTO: SONALI SENARATNA SELLAMUTTU/IWMI

Figure 8: Geology of the Dry Zone. Hydrogeological cross-section illustrates the sequence of strata in the Monywa to Chaung-U area *(Source: Main map adapted from FAO 2008; cross-section modified from GDC 1984. Note:* 1 foot = 0.3048000 meters; 1 mile = 1.60934 kilometers).



CHAPTER 3:

Improving irrigation infrastructure

Irrigation began in the Dry Zone in the eleventh century under the reign of Anawrahta Minsaw, the first king of all of Myanmar. He constructed a series of weirs and tanks to provide water for paddy rice cultivation. Under the British, who ruled between 1824 and 1948, some of the ancient weirs were replaced with permanent brick and concrete diversions. However, these only functioned when the feeder streams were in full flow, thus limiting irrigation to one crop a year. During the period from independence until 1962, irrigation weirs and tanks were built.

Since 1988, the Government of Myanmar has made considerable efforts to expand irrigation, with much of this investment being made in the Dry Zone. According to MOAI, the area covered by irrigation infrastructure in the region is now around 515,000 ha (combined estimates from ID and WRUD). This is equivalent to around 5% of the total area and 12% of cultivated land (JICA 2010). In 2000, the government set a national target to make irrigation available for 25% of agricultural land, with the emphasis on providing water for cultivating summer paddy.

Types of irrigation

The majority of irrigation schemes in the Dry Zone are gravity-fed canal systems that draw water from storage dams or weirs and are managed by ID (Figure 9). These canal irrigation schemes were designed mainly for irrigating paddy fields. ID reports 89 schemes in Mandalay, Magway and Sagaing[5], with a total command area of around 344,000 ha. These include major schemes (> 10,000 ha) at Kinde and Sinthe (Mandalay); Natmauk, Kyiohn-kyiwa, Mann Caung and Salin (Magway); and Ye-U, downstream of the Thaphanseik Dam (Sagaing).

Since 2000, there has been a focus on developing large pump irrigation projects that draw water from rivers using high-discharge pumps. WRUD has implemented 18 schemes covering more than 71,000 ha in Mandalay, Magway and Sagaing; another seven projects with a total command area of almost 50,000 ha are either planned or under construction. WRUD also lists 165 completed smaller schemes,

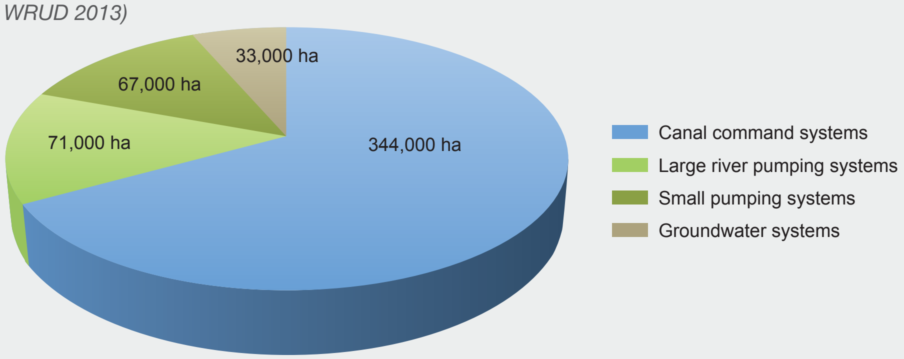
PHOTO: MATTHEW McCARTNEY/IWMI

[5] Figures are for the Mandalay, Magway and Sagaing regions; the Dry Zone lies within these regions, but covers a smaller area.

with an irrigable area of 67,000 ha, along with nine additional projects covering 5,800 ha, which are planned or under construction (WRUD 2013). Pump irrigation projects usually provide water for both rice and non-rice crops. Spate irrigation, which makes use of seasonal floods, has also been trialed, for example, at Shwe Hlan Bo in Mandalay Division, as well as in small village schemes (Spate Irrigation Network 2013).

These figures do not include informal, small-scale pumping from private tube wells, which is becoming increasingly widespread, particularly for growing horticultural crops (see Chapter 4). Although groundwater currently represents only around 5% of formal irrigation, its use is increasing more rapidly than that of other water sources, in part, due to informal use.

Figure 9: **Areal extent of different irrigation types across Mandalay, Magway and Sagaing.**
(Source: WRUD 2013)



Irrigated areas and water use

The extent of irrigation within the Dry Zone is not well established. The MOAI estimate of 515,000 ha for the total command area excludes farmer-managed irrigation outside of formal schemes. Estimates from other sources range from 386,110 ha (JICA 2010) to 685,246 ha (FAO 2008). Current irrigation is primarily used to extend the wet season growing period or to safeguard wet-season crops, rather than for full irrigation of dry-season crops. Previous government programs mandated production of rice on *le* (paddy) lands, and promoted production of summer paddy in irrigation systems. Most formal irrigation systems have areas designated for paddy and other crops, although control over the types of crops cultivated has now been relaxed.

The actual area irrigated is likely to be much lower than the estimates of the total command area. For example, WRUD reported that, in 2012-2013, only 26% of the nominal area of the Nyaung-U Pumped Irrigation Project was actually irrigated in the wet season and 15% in the dry season. 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." They concluded that some reservoirs and diversion dams could not supply water at all.

IWMI scientists mapped the actual irrigated area of the Dry Zone during the dry season from November 2011 to April 2012 using Google Earth images. Areas actually irrigated were generally distinguishable from non-irrigated dry fields by their green color (Figure 10). Riverbank recession agriculture and any areas of cropland growing on residual moisture were indistinguishable from irrigated crops, and were hence included in the analysis. IWMI calculated the total delineated area to be 260,000 ha, including both formal and informal irrigation. This work confirmed that the actual area irrigated in the dry season is considerably less than the official command area of formal irrigation schemes.

This situation does not, on the whole, reflect a physical shortage of water. ID estimates withdrawals for the 344,000-ha canal command area in the Dry Zone to be 7,536 Mm^3y^{-1}. This is a very small amount compared to river flow, representing less than 3% of the total flow of the Irrawaddy River.

Currently, the availability of surface water from rivers and storage is less limiting than access; infrastructure is scarce in remote areas located away from the major rivers, and the costs of pumping are often prohibitive.

Figure 10: Satellite image captured during 2015 around Kyauktan in the Dry Zone, showing the clear greening effect of irrigation *(Source: Google Earth, image © 2015 CNES/Astrium).*

In addition, current irrigation efficiency is very low (Box 5). IWMI's calculation that, at best, only about 5% of the water diverted for irrigation is effective in contributing to crop transpiration suggests that there is scope for improving the efficiency of irrigation schemes within the Dry Zone.

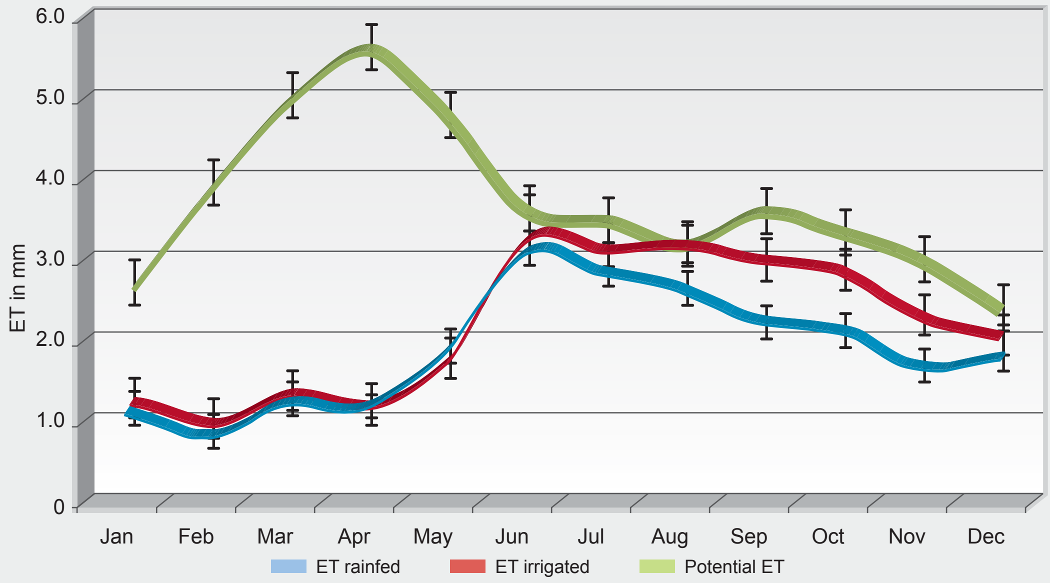
Box 5: How much water do farmers in the Dry Zone need?

To estimate irrigation water requirements across the Dry Zone, IWMI scientists compared evapotranspiration (ET) from irrigated fields and nearby rainfed crops identified from Google Earth images.

Monthly ET during the period 2011-2012 was estimated using MODIS 16 global ET data. For fully irrigated fields, actual ET should be close to potential evapotranspiration (PET). During the height of the wet season, between June and August, irrigated and rainfed areas around the edges of the Dry Zone exhibited actual ET rates close to PET. This indicates that irrigation was not significantly beneficial to wet-season crops in these areas in 2011 and 2012, presumably because rainfall was sufficient to enable crop growth. In contrast, in the center of the Dry Zone, rates of actual ET from irrigated areas remained above those from rainfed areas throughout July to September, highlighting the important role of irrigation in supporting wet-season crop growth in this region (Figure 11). The incremental ET due to irrigation was apparent during September to November, but actual ET of both rainfed and irrigated areas during December to April was significantly below PET, indicating that there was negligible irrigation during these months.

Over the years 2011 and 2012, irrigation enabled between 22 mm and 106 mm of additional ET depending on the location. This equates to a maximum estimate of 386 Mm³ of irrigation water over the 340,000 ha of irrigated canal command areas managed by ID. Compared to its estimate of 7,536 Mm³ for irrigation withdrawals, this indicates that, at best, only about 5% of the water diverted for irrigation is effective in contributing to crop transpiration.

Figure 11: Average monthly actual evapotranspiration (ET) rates (mmd^{-1}) during 2012 for rainfed and irrigated locations in the Dry Zone (around the confluence of the Chindwin and Irrawaddy rivers), showing enhanced ET from irrigation during July to December.
Note: Error bars correspond to standard deviation between the five points used to compute ET.



Constraints to irrigation

So, why are the actual irrigated areas and overall efficiency of irrigation so low? A major issue for pumped irrigation projects is the availability and cost of energy for pumping, although many other factors also affect the performance of formal irrigation schemes. These include: (i) problems with the design, operation and maintenance; (ii) inappropriate siting of infrastructure and soil characteristics; and (iii) lack of agronomic advice to help farmers make the best use of irrigation. These issues are compounded by inadequate funding, and by communities having insufficient technical capacity to operate and maintain facilities in the long term.

Irrigation is highly subsidized; although there are charges for water, these are not sufficient to cover operational costs. Farmers pay a standard MMK[6] 9,000 per acre per season for full irrigation of paddy in the dry season; MMK 6,000 per acre per season for irrigation of non-paddy crops in the dry season; and MMK 3,000 per acre per season for irrigation during the wet season, regardless of the type of crop. WRUD staff in Nyaung-U estimated the actual operational cost for pumped irrigation projects (including pumping and maintenance, but excluding capital costs) to be around MMK 40,000-45,000 per acre.

How water is managed and distributed within irrigation schemes is critical. IWMI's community-level survey indicated that unequal distribution of water, which causes crop failure, and leads to conflicts between head- and tail-end farmers, often resulted from a lack of clear and transparent institutional arrangements. Without a coherent structure in place, water management committees and WRUD are not able to regulate and coordinate water distribution adequately.

Using irrigation wisely in the future

Where farmers have access to formal irrigation infrastructure, repairing and improving the systems is a high priority. IWMI's community-level survey showed that, for villages practicing year-round irrigation, rehabilitating or extending existing irrigation infrastructure was the most preferred water management option for landed farmers, and the second-most popular option for marginal and landless farmers. This reflects the fact that agriculture represents 33% of the income portfolio of marginal farmers in irrigated areas, and between 38% and 58% of the income of landless villagers through casual labor.

The government and development partners have explored options for rehabilitating formal irrigation infrastructure. For example, Anderson Irrigation and Engineering Services Ltd. (2012), on behalf of the United States Office for Project Services (UNOPS), looked at increasing the efficiency and effectiveness of pumped irrigation schemes. While they seem like obvious targets for investment, rehabilitating and expanding formal irrigation schemes should be approached with caution. The costs are high and, until the factors constraining the performance of current irrigation schemes are better understood and managed, the risks are also high.

For example, unless the energy required for pumping can be guaranteed, investments in rehabilitating or constructing pumped irrigation projects may be lost. The report by the Auditor General's Office quoted previously recommended that inefficient irrigation schemes should be abandoned, not rehabilitated.

[6] MMK 1 = USD 0.00089 (exchange rate as at June 2015).

Assessing the effectiveness of irrigation

Before investments are made, interested parties should assess the relative effectiveness of the different modes of irrigation (gravity schemes, pumped irrigation projects, groundwater, and small-scale, farmer-managed pumping from surface water and groundwater) in terms of the impacts on water and energy productivity, as well as yields, farm incomes and livelihoods. It is important that irrigation is analyzed for its role in increasing living standards and reducing poverty, as well as determining whether it is economically and technically viable.

PHOTO: ROBYN JOHNSTON/IWMI

Formal irrigation schemes 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 households (since they cover, at most, 16% of cultivated land). However, as IWMI's community-level survey preferences indicated, the landless also benefit through employment.

Experience from other countries suggests that irrigation alone is unlikely to make a big difference to the incomes and livelihoods of farmers. Investments are needed to structure input and output market chains, so that farmers have access to high-quality seeds, fertilizers and pesticides, and are able to procure a fair price for their crops. Also, if farmers are to make the best use of irrigation through good crop choices, and employing suitable in-field soil and water management techniques, they require extension services providing sound agronomic advice. Commodity exchange centers, wholesale warehouses and storage facilities are also important.

The government's agricultural policies related to summer paddy production and crop diversification have been important drivers of irrigation development and management. As Myanmar moves from centralized to decentralized policies, reforming and revitalizing formal irrigation systems will require redefining the roles, responsibilities, tasks and expectations of the government and communities around operating and maintaining these systems. Past irrigation developments have not necessarily reflected farmers' needs and priorities. Future approaches must allow local communities to represent their aspirations for irrigation development, and to influence the type of schemes implemented and how they are managed. This will likely require some capacity building within communities.

CHAPTER 4: Investing in groundwater

Groundwater for domestic use and livestock watering

Groundwater is a critical resource for domestic and village use in Myanmar. Nationally, about 45% of people draw their drinking water from protected or unprotected dug wells, and another third from tube wells. WRUD estimate that, in Mandalay, Magway and Sagaing, 6.65 million people have access to domestic water supplies from more than 13,700 wells, two-thirds of which are deep (WRUD 2013). In many villages, multiple sources are used to access domestic water supplies seasonally. Drinking water is primarily accessed from wells, but water for livestock and washing is drawn from open ponds in the wet season or shallow wells in the dry season.

Village ponds often dry out early in the dry season and villagers will then revert to more reliable subsurface supplies. Substantial gains have been made in developing safe water supplies since the mid-1980s, when only one-fifth of village domestic supplies were derived from tube wells, but unprotected shallow dug wells are still a relatively important source of water within villages in the Dry Zone. The high mortality rate of children under 5 years old (38 per 1,000 live births [JICA 2010]) is partly attributed to waterborne diseases from unprotected sources.

IWMI's community-level survey confirmed the success and importance of deep tube wells for village water supplies. Such wells, with motorized pumps providing a flow at 6.8 m^3/h, can supply domestic water for an average village with 800-1,000 inhabitants (JICA 2007). The wells provide reliable, high-quality water during all the seasons, benefiting the entire community. After installing deep tube wells in villages, JICA (2007) reported a reduced time for fetching water, fewer cases of diarrhea, dysentery and skin diseases, and increased water consumption in poor households. In most cases, deep wells are used exclusively for domestic and livestock purposes (and often primarily for drinking water) due to the cost of pumping.

The cost of installing a well and electric pump for a village system can be as high as USD 40,000 (JICA 2010). However, the Japan International Cooperation Agency (JICA) reported a high success rate in drilling, with all 49 wells in their study capable of delivering the required volume of water. Maintenance of pumps is an ongoing concern, requiring support. JICA addressed this by training engineers, and establishing village water committees to manage the water supply and maintain pumps (JICA 2007). IWMI's study only identified one community where drilling for water had been unsuccessful.

PHOTO: MATTHEW McCARTNEY/IWMI

The high cost of wells can drive communities to seek alternative lower-cost water supplies, such as shallow wells or rainwater collection from rooftops. Shallow tube wells using manual or motorized lifting equipment are important for village supplies, but the quality and quantity of water from shallow aquifers are less reliable. For shallow wells, the NGO Proximity has developed cheap, plastic (so-called 'baby elephant') foot pumps that, at USD 13, are a fraction of the price of conventional treadle pumps. These are limited to water tables within 8 m of the surface, although pressure pump models are available that can lift water from greater depths. Solidarités International has had success with implementing village-level solar pumps for domestic water supplies under a payback scheme. The United Nations Children's Fund (UNICEF) and ADRA have also undertaken trials of using solar pumps for supplying water for domestic purposes.

Groundwater for irrigation

Large- and medium-scale groundwater irrigation projects have been developed at multiple locations in the Dry Zone, based on both pumped and artesian systems. Around 33,000 ha are already irrigated under groundwater schemes, with plans to expand this to almost 100,000 ha (Johnston et al. 2013). However, this is only part of the story. As in other parts of Asia (Mukherji et al. 2009), the advent of affordable small, motorized pumps is resulting in the rapid expansion of small-scale, individually managed pumping in Myanmar. Pumping groundwater for irrigation is emerging not only in rainfed areas, where expected, but also within irrigation command areas where there are shortfalls in supply.

Small-scale, farmer-managed pumping has significant advantages over formal irrigation in terms of its flexibility, reliability, ease of use and simple maintenance. Where groundwater supplies are available and sustainable, it has proved to be an affordable and effective way of increasing production. As an added benefit, the water is also commonly used for domestic and livestock purposes. In IWMI's community-level survey, all types of farmers (landed, marginal and landless) expressed a strong preference for shallow wells with diesel pumps over communal deep wells with electric pumps to access water for irrigation, presumably on the grounds of cost, flexibility and autonomy.

Existing groundwater infrastructure

A study tour to the Dry Zone in February 2013 identified four main types of groundwater use for agriculture:

- *Deep tube wells*
  Typically drilled to more than 30 m in depth, deep tube wells are used in formal irrigation schemes implemented by WRUD, usually with funding or support from international donors. Examples are the Monywa Groundwater Irrigation Project and the 99-pond Yinmarbin Artesian Zone Project, both in Sagaing Division. These systems typically draw water from deep tube wells and rely on dedicated multi-phase power supplies for large electric pumps. In some cases, such as at Yinmarbin, naturally 'free-flowing' artesian groundwater occurs. They support command areas fed by a distribution network of lined and un-lined canals.
- *Shallow tube wells and permanent dug wells*
  Typically less than 30 m deep, these wells require much lower upfront and ongoing capital investments, and are mostly financed and managed by farmers, either individually or in small groups. Small motorized pumps are used to lift the water. Usually, these wells irrigate small areas of high-value crops, such as vegetables, which are grown to supply local or regional markets. In some cases, a mixture of surface water and shallow groundwater sources is used, dictated by seasonal availability.

- *Shallow dug wells*
  These wells are constructed annually in alluvial riverbeds *(kaing-kyung* lands*)* when water levels recede during the pre-monsoon season. Villagers construct rudimentary wells or pits and then extract water using ropes and buckets, human or animal-operated mechanical pumps or, occasionally, treadle or motorized pumps.
- *Indirect pumping*
  This is opportunistic dry-season irrigation, where farmers draw water from the open pools present in irrigation canals using 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.

Availability and sustainability of groundwater resources

Although existing estimates of groundwater resources in the Irrawaddy and Chindwin river basins are high (Le Huu Ti and Facon 2004), district-level estimates of groundwater recharge rates suggest that the Dry Zone only has around 4,777 Mm^3y^{-1} of replenishable resources. As previously mentioned, to facilitate long-term use, this moderate resource must be planned and developed carefully.

PHOTO: SONALI SENARATNA SELLAMUTTU/IWMI

At district level, current withdrawals relative to annual replenishment levels vary from 5% in Monywa to 55% in Sagaing, with a district average of 23%. This highlights the potential to extend the area being irrigated by exploiting groundwater. Assuming that around 50% of the annual recharge should be retained to underpin ecosystems and environmental services (Pavelic et al. 2012), IWMI estimates that a further 110,000 to 330,000 ha of land could be irrigated, depending on the water demand associated with the crops selected and local climatic conditions (Table 1).

Table 1: Groundwater use as a percentage of annual recharge (2000/2001) and the potential for expanding irrigation.

Division	District	Groundwater utilization (%)[1]	Potential new groundwater irrigation area (ha)[2]		
			500 mmy^{-1}	1,000 mmy^{-1}	1,500 mmy^{-1}
Sagaing	Monywa	4.8	52,752	26,376	17,584
	Shwebo	8.7	90,146	45,073	30,049
	Sagaing	54.9	0	0	0
Magway	Magway	17.5	38,600	19,300	12,867
	Thayet	13.8	24,702	12,351	8,234
	Minbu	19.2	16,376	8,188	5,459
	Pakokku	9.8	61,951	30,975	20,650
Mandalay	Kyaukse	36.8	3,395	1,698	1,132
	Meiktila	30.7	7,245	3,623	2,415
	Yamethin	23.4	20,607	10,304	6,869
	Myingyan	28.4	10,608	5,304	3,536
	Nyaung-U	26.9	2,414	1,207	805
	District total		**328,796**	**164,399**	**109,600**

[1] Adapted from MOAI 2003

[2] Using figures in previous column supplemented by recharge values (as in Figure 7) and assuming annual irrigation water demands of 500, 1,000 and 1,500 mmy^{-1}

Almost two-thirds of that potential lies in the districts of Monywa, Shwebo and Pakokku, where the most prospective Alluvial and Irrawaddy group aquifers predominate. Monywa and Pakokku, in particular, have limited surface water irrigation, and a high proportion of rainfed lands. The viability of groundwater irrigation from relatively shallow aquifers (8-20 m) has already been amply demonstrated in Monywa. These districts are thus a logical starting point for further investments in groundwater irrigation.

Constraints to developing groundwater supplies

There are areas where it will not be appropriate to develop groundwater resources, because of poor water quality or excessive depths to access the water. Groundwater quality is suitable for general purposes over large parts of the Dry Zone, but salinity and arsenic contamination have caused problems in some areas. For example, in the Monywa irrigation scheme, high salinity precluded the use of some wells and WRUD has documented high arsenic levels in some drinking water wells in the Dry Zone (WRUD 2013). These examples emphasize the need to assess water quantity and quality before implementing major groundwater development projects.

"Developing surface water and groundwater conjunctively is important to ensure the resources are used sustainably"

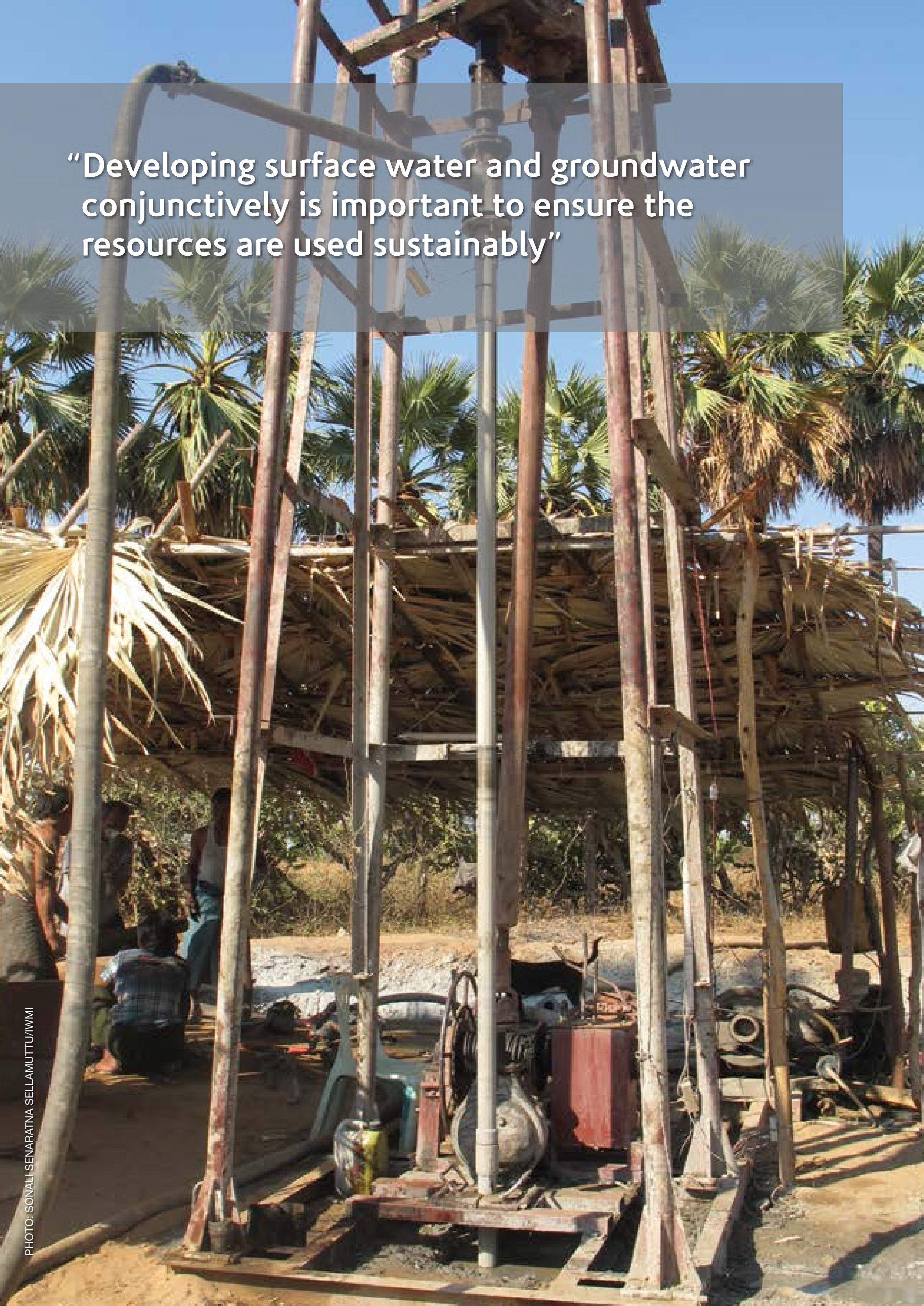


PHOTO: SONALI SENARATNA SELLAMUTTU/IWMI

Ensuring sustainable use of groundwater

Developing surface water and groundwater conjunctively is important to ensure the resources are used sustainably. Surface water infrastructure, if developed strategically, can enhance recharge to shallow aquifers during the wet season. For example, villagers in Ta Ein Tel, in Sagaing, reported that supplementary pumping to their 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.

Before major investments are made, it is essential to gain a better understanding of the sustainability of withdrawals in different systems, recharge dynamics, and impacts of pumping on groundwater inputs to wetlands and baseflow in streams. Community monitoring of wells (Box 6), as part of their routine operation, would provide valuable information in this regard. Assessment of groundwater potential must take into account the possibility of increasing urban and industrial uses. The heavy reliance on groundwater for drinking water means that its depletion could have severe consequences for communities.

If future irrigation strategies rely more on groundwater, new regulatory and institutional mechanisms will be needed. The challenge is to develop locally adapted forms of groundwater governance that include both the government and communities in managing the resource.

Box 6: Livelihood benefits of tapping into groundwater

U Shwe Myaing of Tanpinkan village in Taungtha township constructed a new well 4 months before IWMI's community survey. After years of rainfed farming, he had received a family inheritance, which he invested in improving the water management of his farm. Its upland location called for a deep well. So, he installed a large diameter well from the surface to 6 m, and a tube well from 6 m to 55 m. The total cost was around MMK 1 million. U Shwe Myaing paid MMK 300,000 for drilling, MMK 350,000 for the down-hole pump and MMK 350,000 for a large second-hand diesel engine.

The well irrigates a field of 0.5 ha. For his first irrigated crop, U Shwe Myaing planted onions. Preparing the land took 1 month and cost MMK 100,000. He also incurred diesel costs, which other surveys indicate were likely to be around MMK 30,000 for the season. The soils on his land are calcareous sands with low fertility. So, they required an application of cow dung and urea. The crop was 1 month old when surveyed. U Shwe Myaing anticipated obtaining a yield of 3,000 *viss* (4,890 kg) from this harvest. The selling price at the time was MMK 300-400 per *viss*. He previously produced sesame and mung beans under rainfed conditions. When there was sufficient rainfall, he was able to harvest 10 baskets (about 370 kg) at most, but the crop often failed.

Having access to irrigation means that U Shwe Myaing could now grow watermelons for export to China, with much higher potential returns. However, he chose to initially plant onions, like many other farmers in the area, due to his lack of experience and the relatively lower risk of onion cultivation. He had previously pumped water from open pools to supplement rainfall, but chose to invest in groundwater pumping so that he could irrigate his crops in the dry season and be more assured of a successful harvest.

CHAPTER 5: Rainwater harvesting: Village ponds and farm dams

PHOTO: MATTHEW McCARTNEY/IWMI

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 represent a simple, proven technology that is already common throughout the Dry Zone. In many cases, they only provide a seasonal resource for 7-8 months a year and dry up during the dry season, but they are a critical component of water security.

Of the 24 villages included in IWMI's community-level survey, 17 used ponds as a seasonal resource that provided water between 2 and 12 months a year. Most villages had more than one pond, which they used for domestic and livestock supplies. Some had multiple ponds (more than 30 in one village); these were used for various purposes, including irrigation.

Planning appropriate ponds

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, small-scale irrigation, and small businesses such as brick-making and handicrafts. The type, design and siting of such ponds are very specific to each location and to their potential uses. Dug earth dams are very common, but do not suit all contexts. Other options include subsurface and sand dams (formed by embankments in streambeds), and ring/turkey nest dams (built above the ground and filled by pumping water from rivers). Ponds may be coupled with systems to improve access, such as pipes, pumps or access points, and livestock watering troughs.

Village ponds can be used for supplementary irrigation, particularly in the wet season when they are regularly replenished. In the dry season, the imperative to conserve water for domestic uses and livestock watering often overrides agricultural uses, unless the pond is large. Negotiation as to what constitutes appropriate use of water from village ponds requires collaboration between multiple users and social groups.

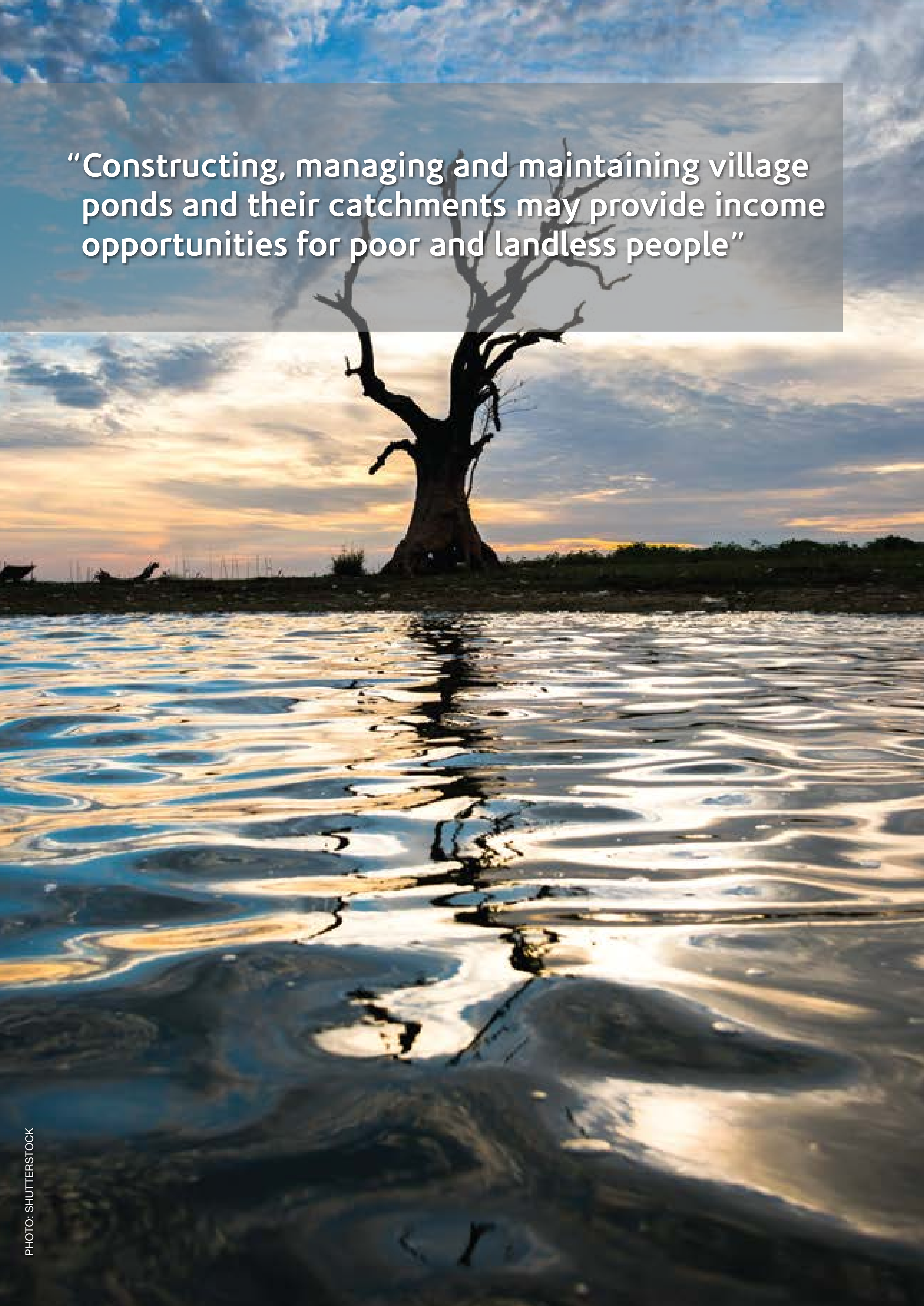
If using pond water for irrigation is planned, dedicated ponds for this purpose may be preferable to using multiple-use facilities, in order to reduce water-use conflicts and because of the relatively larger volumes of water required. These dedicated ponds can be situated in the fields, close to the point of use. Individually owned, small farm reservoirs have proven to be an effective way of providing supplementary irrigation in rainfed areas of Thailand and India with similar agro-ecosystems to Myanmar's Dry Zone. Such systems make it more viable for farmers to plant two crops in a season, rather than one.

In areas with landholdings larger than 2 ha, a commonly used model in Thailand and India is for farmers to sacrifice around 10% of their land to construct a small irrigation water storage facility. Where farm sizes are smaller, communal facilities constructed and managed by a group of farmers may be more appropriate. These are analogous to village ponds, but have a smaller group of users. The size (and number of farmers involved) can vary, but a typical pond serves around 10 ha.


PHOTO: PAUL PAVELIC/IWMI

The cost of building a pond varies considerably depending on its size and type. The cost for a small irrigation dam serving 10 ha in the Dry Zone is estimated to be around USD 6,000. In Dewas District of Madhya Pradesh, India, a very successful program of small dam irrigation has been carried out; over 5,000 dams were constructed, with significant gains in farm incomes. The average cost of these ponds was USD 2,600, the payback period was 3 years and the cost-benefit ratio was 1.5-1.9. The local administration offered a subsidy of USD 900-1,400 to encourage uptake (Malik et al. 2012).

In most cases, communities already have the skills to construct and maintain water storage structures, but they may need technical advice, community payments for labor or access to machinery. In Myanmar, ID provides technical assistance for constructing ponds, and has a fleet of equipment and staff that



"Constructing, managing and maintaining village ponds and their catchments may provide income opportunities for poor and landless people"

PHOTO: SHUTTERSTOCK

can carry out the work. In 2012, ID helped to renovate or construct 200 ponds in the Mandalay Division. NGOs such as ActionAid, ADRA, Solidarités International, and Proximity also have considerable experience of constructing and rehabilitating village ponds. For example, Proximity renovated 260 ponds during 2012.

Potential issues when harvesting rainwater

Evaporation is a major problem when harvesting rainwater, with losses between 50% and 100% commonly experienced. These losses can be reduced by constructing deeper ponds. Seepage losses can be reduced by siting dams on areas of clay soils, compacting the base during construction or lining the pond with clay. Because seepage recharges shallow groundwater, it is also possible to capitalize on these losses by constructing wells nearby.

Spillways, which carry away excessive water, must be well designed and maintained. Many small dams fail because they are overtopped in a flood, often because the spillway is inappropriately designed or because it has been neglected or become overgrown with vegetation. In 2010, Cyclone Giri destroyed a large number of rainwater harvesting structures in both the Mandalay and Magway divisions, as they were not built to withstand such heavy rainfall.

Maintenance, including the removal of silt and repairing walls, is required at least every 2 or 3 years and, in many cases, annually. Village ponds are usually managed by the community, but may be managed by ID or collaboratively between ID and the community. Unless the community commits to maintaining the structures, investments will be lost. Some organizations, such as Solidarités International and iDE, have set up water management groups within villages to maintain rainwater harvesting storage infrastructure.

The viability of ponds and small dams often declines due to siltation or because embankments collapse during floods. Many soil and water conservation techniques have been developed to reduce runoff and erosion, including hillside terraces, stone or vegetation bunds, gully plugs, and earthen or stone banks. Planting trees, grasses and shrubs can also help to stabilize soils. Relevant techniques for the Dry Zone are described in detail in Carucci (2001) (see also Chapter 6).

Ensuring long-term viability

The fact that so many small reservoirs in the Dry Zone require rehabilitation is a testament to the difficulty of ensuring long-term maintenance. Programs to construct and maintain village ponds need to explore technical and social approaches to ensuring long-term viability.

On the technical side, guidelines can highlight appropriate designs for rainwater harvesting structures in different contexts. Before construction, site analysis is vital to ascertain the capacity, cost, risk of siltation, potential life span, and interactions between surface water and shallow groundwater, including the potential to use small reservoirs or sand dams to recharge aquifers.

Roles and responsibilities for managing and maintaining rainwater infrastructure at the village level must be clearly defined. Currently, community water user groups are the most common model for management, but other approaches could be explored. Management extends beyond the pond; it should include watershed management programs in catchment areas of ponds to protect inflows and water quality. Constructing, managing and maintaining village ponds and their catchments may provide income opportunities for poor and landless people within the community.

CHAPTER 6:
Managing water in the landscape

Soil erosion and land degradation are widespread in the Dry Zone. The main causes are poor farming practices, overgrazing, deforestation due to agricultural expansion, commercial and illicit logging, excessive cutting of trees for charcoal and fuelwood, and shifting cultivation. All of these are exacerbated by population growth. Land degradation results in decreased production (through loss of topsoil and nutrients), loss of productive land (through gullying and reduced vegetation cover) and impacts on infrastructure (through silting up of ponds, sedimentation in canals and damage to pumps from high sediment loads in the water). High sediment loads also pose a major challenge for navigation on rivers, particularly in the dry season.

Slowing the rate at which water moves through the landscape can help reduce erosion, improve soil water availability, and increase recharge (the so-called Recharge, Retention and Reuse [3R] approach of van Steenbergen et al. [2011]). At the core of this approach is the buffer function provided by integrated management and storage of groundwater, soil water and rainwater. It is important because, even if the Government of Myanmar is able to fulfill its target for expanding irrigation to 25% of cultivated land, the majority of farmers in the Dry Zone will continue to be reliant on rainfall.

The problem of degraded land

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 threatened, by agricultural encroachment and the intensification of shifting cultivation (Leimgruber et al. 2005). Although shifting cultivation is often cited as a major cause of deforestation, evidence indicates that it is shortening of the fallow period (usually due to population pressure) that causes problems, rather than shifting cultivation per se. Traditional *taung-ya* methods of shifting cultivation, with sufficiently long rotations, can help to conserve natural forest ecosystems and biodiversity much more effectively than plantation monocultures (Khin Htun 2009; Valentin et al. 2008).

The problem of land degradation in the Dry Zone was identified as early as the 1950s, when a government project was initiated to plant trees on degraded lands. The United Nations Development Programme (UNDP) and FAO undertook watershed management programs during the 1990s (Cools 1995;

PHOTO: ISTOCKPHOTO

Carucci 2001; Kahan 2001). In 1997, the Dry Zone Greening Department (DZGD) was established to manage land degradation. Despite these initiatives, and a proposed DZGD-integrated plan for the years 2001-2031 covering forest conservation and land management, it is not clear that these programs have been effectively implemented or that there has been a significant change in the rates of land degradation.

Land degradation has reached critical levels in upland areas around Pauk in Magway Division, with widespread gullying and topsoil depletion (Karin Luke, Welthungerhilfe [WHH], pers. comm.). Changes in river morphology, caused by large volumes of sand, have clogged irrigation canals, making them unusable. Community forest conservation and agroforestry projects have had some success, but these were at a small scale. There is an urgent need to scale up such successes to a regional level, since degradation has spiraled beyond the extent at which it can be tackled by small projects.

Retaining water in the landscape

At the field scale, techniques to reduce erosion enhance infiltration and water retention in the soil profile, and increase the effectiveness of rainfall. Cools (1995) reported the use of a range of traditional Soil and Water Conservation (SWC) practices in the Dry Zone, including overflow bunds, gully plugging with rocks or crop residues, strip cropping and agroforestry techniques. Other promising approaches include deep tillage, reduced tillage, zero tillage, mulching, planting basins and growing crops that require little water. FAO has developed a detailed manual of SWC techniques specifically targeted for the Dry Zone (Kahan 2001). As agronomic practices, they need to be introduced to uninitiated farmers as part of agricultural extension services.

At landscape scales, similar approaches can be used to prevent erosion, improve water retention and infiltration, and enhance recharge to shallow aquifers. Approaches include check dams, vegetated strips, infiltration basins and flood spreading (see van Steenbergen et al. 2011). Increasing vegetation cover is a key component of watershed management, which is achieved by conserving existing forest patches, planting new vegetation, employing agroforestry methods, and building enclosures to reduce grazing pressure. Free grazing can be a significant driver of erosion, particularly in the uplands, where sheep and goats are common.

Conservation zones protect riparian vegetation and reduce riverbank erosion. A 30 m exclusion zone along streams was previously enforced in the Dry Zone, but has been abandoned in the past 20 years (Karin Luke, Welthungerhilfe (WHH), pers. comm.). Such catchment-scale approaches are vital to reduce sedimentation in small reservoirs. When planning SWC projects, it is essential to match interventions and incentives to local conditions. For example, farmers consulted during IWMI's community-level survey recalled that contour banks had been unsuccessful because livestock had destroyed them, while hedgerows and vetiver grass banks had been much more effective. In their experience, successful programs usually had a dual focus on retaining water and preventing erosion.

Programs to address sediment issues will not be successful unless they address ongoing land degradation and deforestation in the mountainous headwaters of the major rivers (including the Irrawaddy), which lie outside the Dry Zone. The Irrawaddy River has one of the highest sediment loads of all the rivers globally, but the extent to which current sediment levels are natural (and hence must be managed) or anthropogenic (and could potentially be mitigated or reduced) is not clear. A basin-scale analysis of sediment sources and dynamics is needed to support planning, since approaches to managing and mitigating sediment in the river will vary significantly depending on its source and distribution.

“It is important that the ‘public good’ nature of soil and water conservation initiatives is recognized and the costs are shared”

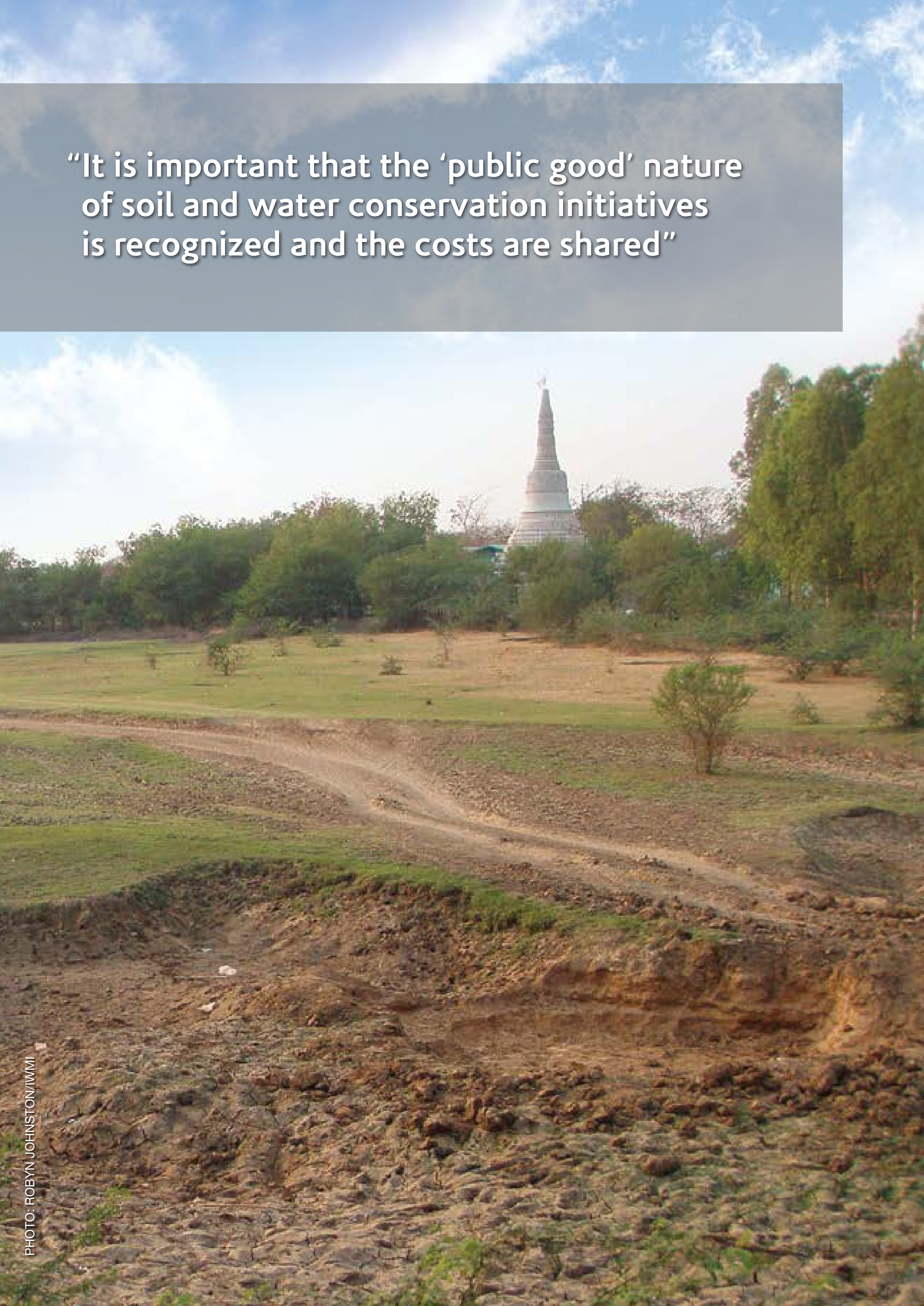


PHOTO: ROBYN JOHNSTON/IWMI

Putting soil and water conservation into action

Despite the importance of, and long-term benefits brought about by, SWC approaches, they did not emerge strongly as a priority from IWMI's community-level survey. Similarly, although Cools (1995) demonstrated the positive economic returns from SWC measures at farm level in the Dry Zone, he found that farmers were often failing to implement even traditional approaches. As farm sizes decrease, and farmers have lower incomes and fewer savings, funds are simply not available for SWC. In many cases, the benefits may not be apparent for several years and they may accrue downstream, outside the areas where projects are implemented.

It is important that the 'public good' nature of SWC initiatives is recognized, and the costs are shared accordingly. Incentives and external financial resources may be needed to encourage farmers to implement SWC projects on any significant scale. Under the United Nations Human Development Initiative of the 1990s, fertilizers were provided to participating farmers as incentives for erosion control; this was generally considered to be a successful incentive. Micro-credit programs have not usually been successful for watershed management and SWC programs, as the benefits are not immediate. Current programs under the French development NGO GRET, Solidarités International and others emphasize the importance of finding appropriate incentive structures to interest farmers and communities. Although communities often express their support initially, it can be difficult to maintain their interest, particularly for programs such as grazing management. Cools (1995) highlighted that participatory approaches may not be appropriate for SWC at village to watershed level, since more pressing priorities to address the symptoms, rather than the cause, may override these concerns.

A review of the outcomes of programs conducted by UNDP, FAO and the Government of Myanmar under the United Nations Convention to Combat Desertification (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.

CHAPTER 7: Information for planning and managing water resources

Achieving water security in the Dry Zone requires investment in hydraulic infrastructure and the institutions needed to manage water effectively. A coordinated development strategy based on reliable information is needed to guide future investments in water resources management.

Evidence-based decision making is currently hindered by both the lack of water-related data and its general inaccessibility. Responsibility for water resources is currently spread across at least 15 government agencies. Water-related data in Myanmar are dispersed across government departments and often held by provinces, districts or irrigation schemes.

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, accessible databases and analytical tools. This is of particular importance and urgency for the management of groundwater resources. Continued groundwater development, without assessing the availability of the resource, runs the risk of lost investment through over-exploitation and inappropriate siting of wells.

Significant progress has been made over the last few years. A National Water Resources Committee (NWRC), formed by a Presidential Decree in July 2013 under the chairmanship of Myanmar's Vice President, is taking the lead in coordinating water resources planning and disseminating information across sectors. In December 2014, the World Bank announced a USD 100 million donation for the Ayeyarwady [Irrawaddy] Integrated River Basin Management Project (AIRBMP), which aims to strengthen water resources management and planning, and enable informed decisions about future investments in developing the river. The project will support the expansion and modernization of hydrometeorological observation, early warning and information systems, as well as facilitating navigation to make water transport safer and more economically viable (World Bank 2014). The Myanmar Integrated Water Resources Management Strategic Study, a collaboration between Myanmar and the Netherlands, was completed in 2015, and included recommendations for a national master plan on water management and assistance for improving hydrologic data collection.

If these projects are implemented successfully, Myanmar will be better placed to increase agricultural production, reduce poverty and improve livelihoods through well-planned and sustainable management of the valuable water resources of the Dry Zone.

PHOTO: PAUL PAVELIC/IWMI

"A coordinated development strategy based on reliable information is needed to guide future investments in water resources management."

PHOTO: ROBYN JOHNSTON/IWMI

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