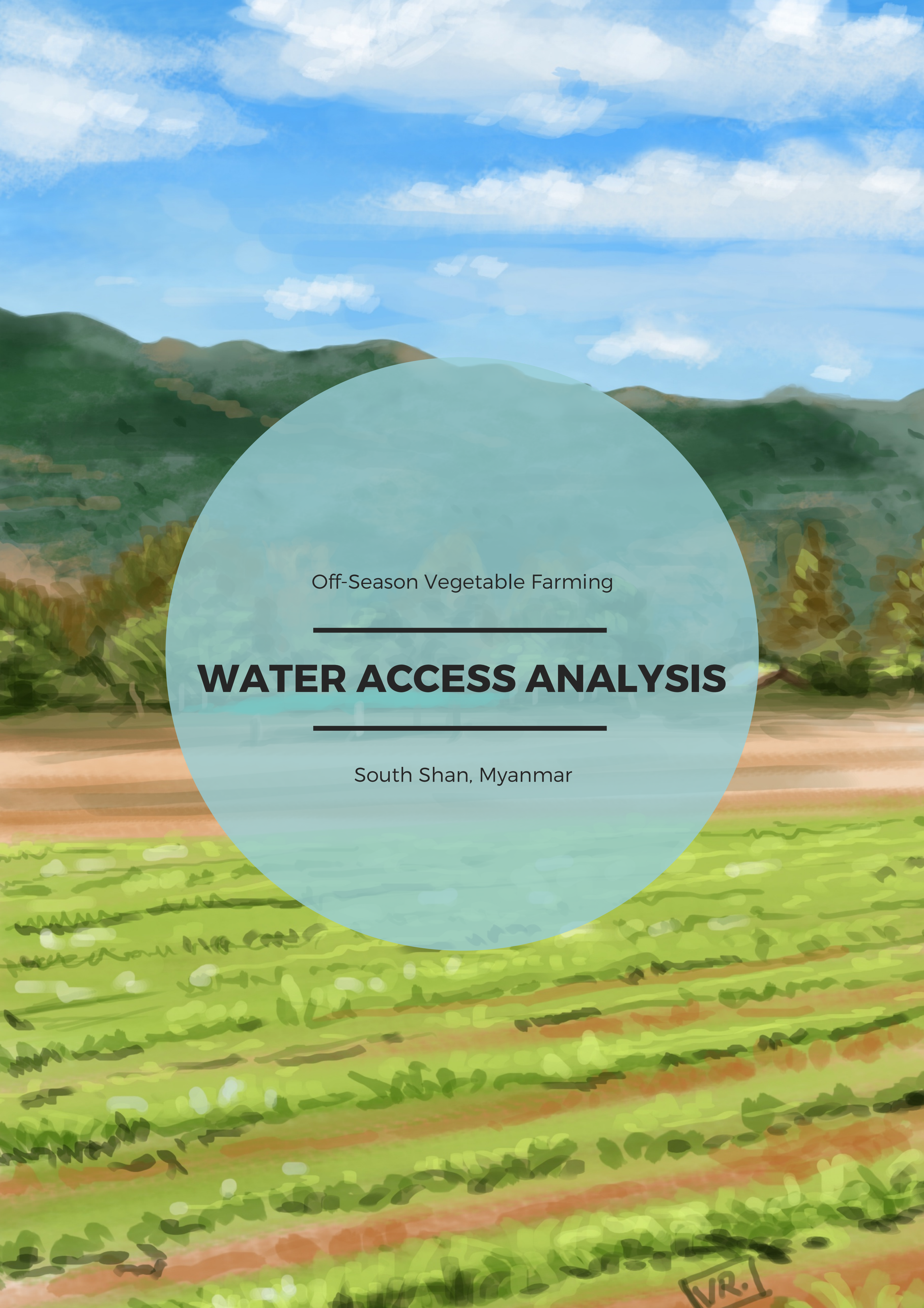

Off-Season Vegetable Farming

WATER ACCESS ANALYSIS

South Shan, Myanmar

Project

This study was carried out between January to February 2017 as part of the Livelihood and Food Security Trust (LIFT) funded Making Vegetable Markets Work (MVMW) project.

Author

Christian Snoad, of Freeway Associates, an independent water, sanitation, hygiene and markets consultant.

Contributors

Dr Sajid Pareeth, a GIS expert based in Italy, conducted the remote sensing cropped areas analysis.

Roman Perkhaliuk, a GIS technician based in Ukraine, produced the surface water map.

Acknowledgments

Thanks to independent consultant Melvin Woodhouse for providing inputs regarding the approach.

Donors

This study was funded by:

Mercy Corps, Myanmar

Cover image: Pindaya township, Zaw Gi village. Photo by Christian Snoad, digitally hand-painted by Vijendra Raikwar.

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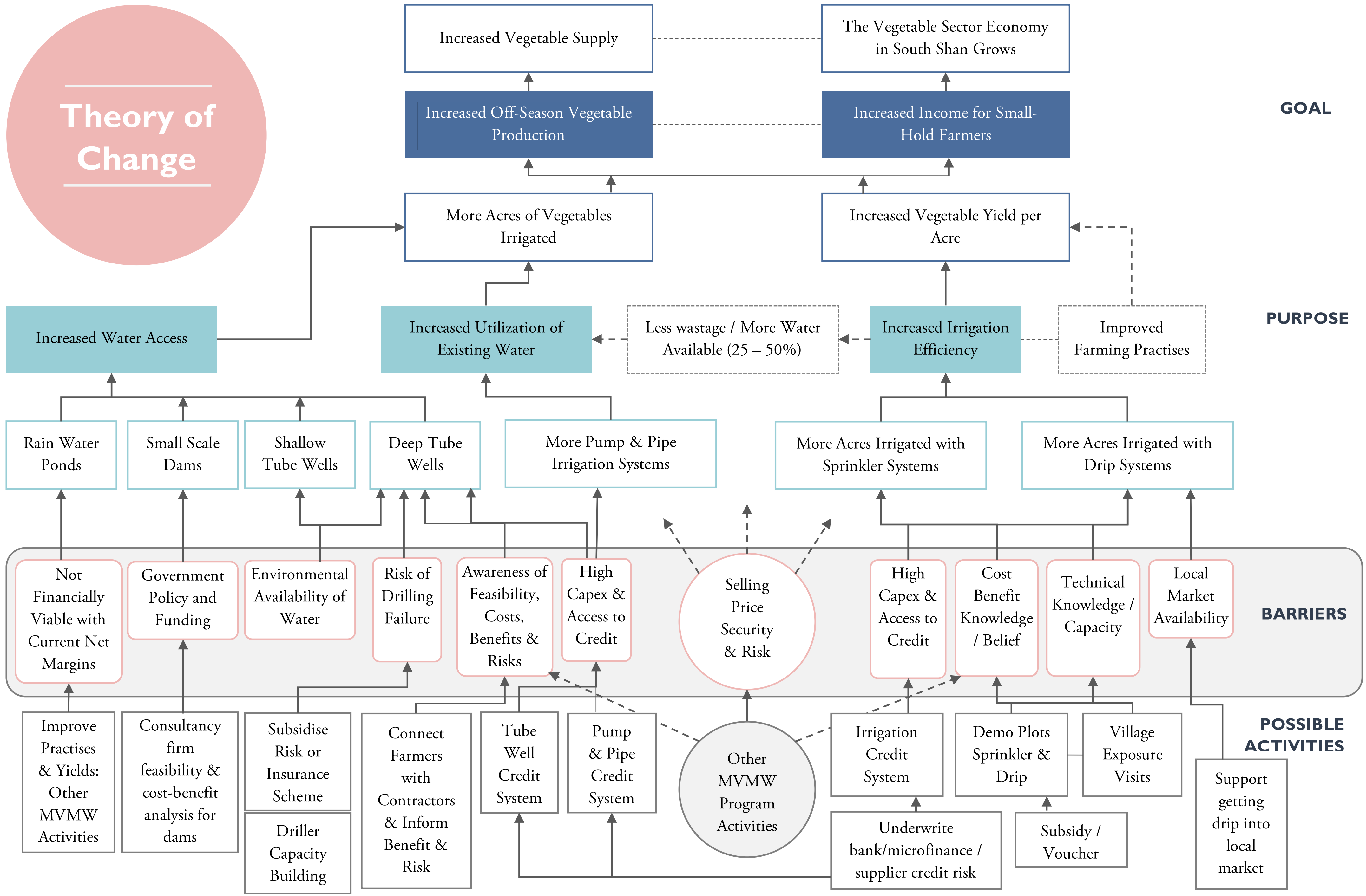
Theory of Change
Increased Vegetable Supply
The Vegetable Sector Economy in South Shan Grows
GOAL
Increased Off-Season Vegetable Production
Increased Income for Small-Hold Farmers
More Acres of Vegetables Irrigated
Increased Vegetable Yield per Acre
PURPOSE
Increased Water Access
Increased Utilization of Existing Water
Less wastage / More Water Available (25 – 50%)
Increased Irrigation Efficiency
Improved Farming Practises
Rain Water Ponds
Small Scale Dams
Shallow Tube Wells
Deep Tube Wells
More Pump & Pipe Irrigation Systems
More Acres Irrigated with Sprinkler Systems
More Acres Irrigated with Drip Systems
BARRIERS
Not Financially Viable with Current Net Margins
Government Policy and Funding
Environmental Availability of Water
Risk of Drilling Failure
Awareness of Feasibility, Costs, Benefits & Risks
High Capex & Access to Credit
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High Capex & Access to Credit
Cost Benefit Knowledge / Belief
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Driller Capacity Building
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Tube Well Credit System
Pump & Pipe Credit System
Other MVMW Program Activities
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Demo Plots Sprinkler & Drip
Village Exposure Visits
Underwrite bank/microfinance / supplier credit risk
Subsidy / Voucher
Support getting drip into local market

Executive Summary

This work aimed to identify the key environmental, social, economic and market barriers to increasing the availability and utilization of irrigation water for off-season vegetable farming across five townships of South Shan. Within the project area, GIS analysis estimated that approximately 68,000 acres are cropped in the off season. We expect that at least half of this is from irrigation with the remainder from residual moisture. During field visits we found 8% of off-season irrigated land utilized local sprinkler systems and less than 1% drip irrigation systems.

By analysing various data sources, we estimate that an average net income per acre for off-season vegetable farming is 800,000 kyats ($640), which doubles to 1,600,000 kyats ($1,280) with improved seeds and farming practises. Combining improved practises with selling at the peak off-season price it is theoretically possible to achieve 2,500,000 kyats ($2,000). Most farmers appear to be selling beneath the average market tracking price.

Overall, in most areas farmers are well utilizing existing spring and stream water. Unlike the dry-zone of Myanmar, pump sharing and rental is not common with approaches instead highly individualized. The main barriers to increasing stream water utilization are access to credit for pumping systems and crop selling price insecurity. Providing a credit system would enable poorer farmers to obtain pumping systems. However, in some areas it may prove a zero-sum-game at the macro level with downstream farmers adversely affected. Payback periods for new individual pumping systems depend on multiple variables but could be expected to be between one and three crop cycles with current unimproved practises.

Regarding new water sources, it is generally considered that most springs have already been found and exploited. Rainwater harvesting ponds were demonstrated to not be economically viable. Shallow groundwater is cheap to access but difficult to predict where it will be. Deep tubewells present a good opportunity to increase irrigation water and would be most suitable in alluvial areas. The aquifers are very likely to be underutilized at present. Payback periods for deep tubewells depend on multiple variables but could be expected between less than one to three crop cycles, with 20-year benefit cost ratios from 7-1 to over 30-1. The main barriers to increasing groundwater utilization are access to credit, the risk of drilling failure and crop selling price insecurity. A credit system and risk sharing or insurance scheme may overcome these barriers. A project of this type would have an opportunity to work on developing the regulatory frameworks and policy for sustainable individualized irrigation water use including systems to prevent over-extraction, building on lessons from the region.

Increasing off-season irrigated acres can also be achieved through more efficient use of existing water. Adoption of sprinkler or drip systems would more than double the effective 'value' of the available water from 220 to 440 kyats net margin per m^3 of water applied for a typical vegetable crop. Drip systems are currently not available in the market and most farmers have not seen drip in practise. There is a clear opportunity to utilize sprinkler and drip systems in demo plots to demonstrate use and cost-benefit. The main barriers to improving irrigation efficiency are a lack of knowledge of use and cost-benefit, access to credit and crop selling price insecurity. Irrigation credit and subsidy schemes would significantly accelerate uptake.

The lack of selling price security is a key underlying factor influencing all farm investment choices and limiting development. Any program which works to increase security and improve consistency in prices will indirectly improve the enabling environment for increasing water access and irrigation.

In Taunggyi township we met farmers who had only recently started cropping in the off-season as a result of learning the skills and potential benefits through the Mercy Corps project. These wealthier farmers made the decision to invest in pump, pipe and irrigation equipment, highlighting the impact of 'non-water projects' on water access.

A second 'Water Access Interventions' report builds on the findings of this report and recommends specific program activities which could reduce key access barriers. The theory of change from that report is included here.

Summary

General

The vast majority of water is from springs

Springs, arising primarily from the karstic aquifer conditions, and the streams and ponds that they produce, form the vast majority of available irrigation water sources. A small proportion of farmers have access to low yielding shallow groundwater, suitable for small plots. Deep tubewells for irrigation are rare and their overall contribution to irrigation is very small.

There is significant heterogeneity

There is significant variation in water availability and practises between and within townships. Each village visited requires a slightly different solution to increase the available water. However, some consistent barriers were widely reported.

Currently 24% of acres are irrigated in the off-season

The latest agricultural census data reports that 24% of crop holdings across South Shan are irrigated, representing 192,017 acres. A remote sensing satellite analysis found that approximately 68,000 acres are cropped in the off-season across the five townships of interest. Potentially around half of this is from residual moisture and half from irrigation.

Crop choice and water requirement

Within the context, cabbage and tomato have a total crop water requirement around 75% greater than garlic and small vegetables[1]. Considering irrigation efficiencies, 75% more water is also 'lost' through inefficiencies. One acre of cabbage grown with 60% efficient furrow irrigation requires the same total quantity of water as 2.36 acres of garlic. Farmers are not making crop choices based on water requirements, but instead primarily on the basis of habit, knowledge and confidence in the selling price. For farmers pumping from a stream there is no incentive to choose crops with a lower total water requirement, whereas there is more theoretical basis to do so for water from private boreholes due to limited supply.

Generally, farmers make suitable pumping equipment choices

The pump and pipe equipment that farmers are buying is theoretically reasonable for their applications. Farmers will commonly slightly oversize the diesel engine, but this has only a small impact on the overall capital and operating expenditure costs. The pumps chosen appear reasonable for their application based on the pump curves obtained. In some cases, farmers are unnecessarily selecting 3" diameter pipe where 2" would be sufficient, increasing the capital expenditure costs. Each pumping system is unique and would require its own detailed calculations to determine the optimal setup. It is suggested that the gains from such an intensive technical support program would not be sufficient to justify the activity. In some areas farmers are not aware of all pumping options and could benefit from visits to other irrigated villages.

Sprinkler and drip systems are not well utilised

Across the ten irrigated villages visited approximately 8% of the irrigated land utilised sprinkler systems, while less than 1% used drip irrigation.

Water management is ad-hoc but functional

The field visits found that water management is ad-hoc and unstructured but appears to sufficiently function with no cases of conflict reported. The general acceptance of the 'nearest and closest has priority' principle could be considered unequitable.

Lack of selling price security is a major factor for water

A primary barrier to increasing water supply, water access and irrigation systems is the fluctuation and lack of security in selling prices. This fear is not conducive to making changes which will cost a significant amount of capital or require credit. If it was possible to run a program that only focused on improving selling price security it is theorised that water access and irrigation uptake would naturally accelerate as farmers become

[1] refers to FAO general category of 'small vegetables'

more willing to take risks and make investments. Furthermore, buyers could incentivise gains in yield and quality which would be a strong motivator for the uptake of improved practises and irrigation.

Lack of credit is a key barrier

The other primary barrier to increased or more efficient irrigation that was consistently reported by farmers is the availability of funds and access to credit. There is currently no credit system available for increasing water access or improving irrigation. As such villages that already have a high level of irrigation coverage have achieved this without access to credit. As farmers witnessed their neighbours profiting from off-season vegetable irrigation, so their understanding of the cost-benefit increased and perception of the risk of investing reduced. For drip irrigation, where the benefits are less known, wealthier farmers who can afford it are not likely to invest. Providing access to affordable credit would accelerate access to water and more efficient irrigation.

Remote sensing GIS analysis provides new insights

This study utilised remote sensing satellite GIS analysis methods to create a map of streams and estimate the off-season cropped areas. Such analysis has only previously been conducted in the dry-zone and is a new contribution for South Shan. The data can form a baseline to assess the macro level temporal impact of projects. It can also be used to create maps identifying areas to be targeted for sprinkler and drip systems.

Increasing Water Availability

Deep groundwater could be exploited further

Based on the rainfall that the area receives and the low utilisation of groundwater, it is likely that the aquifers within the South Shan area are currently under exploited. There is a scarcity of good quality groundwater data making firm conclusions difficult. Two aquifer environments can be categorised, an alluvium aquifer located at the base of valleys and a fracture dominated aquifer located within the surrounding ridges of limestones, siltstones and sandstones. Within alluvium deposited within the valley floors, groundwater is potentially readily available that can be accessed using local contractors. Both the Inle lake and Heho valleys could provide potentially good drilling opportunities. Other possible locations where alluvium deposits are present might include Soung Cherry and sites off the main road heading down to Pinlaung. Other areas are primarily limestone, probably with karst features. Karst aquifers are highly heterogeneous and inherently difficult to drill. There may be large quantities of water exploitable within a fracture system, but a borehole a few metres away may be completely dry.

Groundwater can be cost effective

The payback period of deep groundwater varies significantly due to many variables, primarily influenced by the number of acres which can be irrigated based on the yield of water and the resulting potential net margin. The payback period from irrigating one acre can range from almost four cycles, under current low net margins, to less than one cycle with improved yields and selling prices. With current unimproved practices irrigating 1.6 acres could have a payback period of less than two cycles. Where much cheaper shallow groundwater is found, the payback period would be one cycle with current practises and assuming half an acre can be irrigated. The 20-year benefit cost ratio for deep groundwater ranges between 7-to-1 and 60-to-1.

Facilitating farmers to access groundwater

The cost of establishing a new deep tubewell, including the pump and accessories, typically ranges between 1.2 to 1.9 million kyats ($960 to $1,520). In the event of a failed borehole the cost varies based on individual agreements with the contractor. Mercy Corps could work with local contractors to establish risk sharing arrangements for certain areas and help disseminate this information to farmers though existing networks. A scheme that underwrites part of the cost of failed drilling, reducing the risk for the farmer, could help to facilitate uptake. This could be in the form of an insurance scheme. In lower risk areas, selective credit streams for groundwater prospecting could be considered. It is suggested that supporting the capacity building of local drilling contractors could improve drilling success rates in the future.

Unlike most other South and South-East Asian countries, Myanmar has not yet experienced such a dramatic increase in the use of private wells for irrigation and there is currently no policy or regulatory environment. There is an opportunity to combine any future support for groundwater utilisation with supporting the development of appropriate policies, monitoring systems and regulation.

Rainwater harvesting is not cost effective

Based on the estimated current average off-season income a typical rainwater harvesting (RWH) pond would have a negative 20-year benefit to cost ratio with a payback period of 24 crop cycles. Significant gains in profitability would be needed to make RWH ponds cost effective. If this were to be achieved, the very high capital expenditure cost would likely still be prohibitive.

Most shallow springs have already been found

It is expected that most shallow springs have already been found and exploited, primarily through prospecting for domestic water. Several of the springs observed were first found for drinking water purposes. The potential for further shallow springs is unknown. Further discussion with the DRD and more specific studies could provide more information.

Where shallow groundwater has been found, it is already well utilised

Due to the low capital expenditure cost to establish shallow tubewells, where it is known to be available farmers are already well utilising the resource. The typical cost is less than 300,000 MMK ($240), which includes drilling, the pump and pipe.

Small to medium scale dam projects would increase water availability

According to the Department of Irrigation (DoI) where farmers can build small dams themselves they have generally already done so. Given the hydrology and topography of the area, further small or medium scale dams could be established in many areas to retain water from the rainy season for use in the off-season. Currently the DoI has no budget or instruction to carry out such work, instead focussing on upgrading existing small dams.

Increasing Water Utilisation

Most communities are already well utilising currently available water

We found that six of the ten irrigated villages visited are already well utilising existing water. In the villages where water is not well utilised it is not necessarily wasted, as it remains available for downstream communities.

Mercy Corp is indirectly facilitating a water program

Field visits in Taunggyi clearly showed that through demonstrating the increased income options of off-season vegetable farming some farmers have already been triggered to invest in improving their off-season water access and irrigation. Mercy Corps could try to measure this impact through the endline survey.

New pumping system are good value

Where water is already available in a nearby stream but not being utilised the payback period of installing a pump and pipe can range from less than one cycle for short pipelines to three seasons for long (2,500 ft) pipelines. The 20-year benefit cost ratio ranges from 7-to-1 to 70-to-1 for a one acre plot. The cost of new systems ranges from around 650,000 to 1,600,000 MMK ($520 to $1,280) depending on the distance that is required to be pumped.

Promoting new pumping systems is easier than promoting drip or sprinkler systems

The benefits of a new pumping system are clearer and more easily demonstrable than sprinkler and drip systems. The benefit of new pumping systems can usually be seen from neighbouring farms or villages. Pumps can be purchased second hand and the asset retains some capital value.

Seeing is believing, village visits can trigger change

In two of the ten irrigated villages visited farmers were unsure of whether installing pumping systems with pipelines would be worthwhile and did not know what equipment would be needed. Facilitating village exposure visits for these farmers to villages that already use a range or different pumping technologies, like Nang Ong Ywar Ma in Kalaw, would increase awareness and could trigger new uptake.

Access to credit would accelerate uptake but a cautious approach is needed

The majority of farmers who have not purchased pumping equipment are either further from the water source or have smaller plots and therefore less available cash and income potential. Access to credit would help these farmers and accelerate uptake. However, a cautious approach is suggested as facilitating new pumping systems may not have the expected gains. At the hydrological basin level it could prove to be a zero-sum game if new irrigation comes at the expense of reducing downstream irrigation.

Solar pumping will make sense in the future

People are clearly motivated by labour savings. Half of treadle pump owners in Myanmar have switched to engines. Affordable solar is theoretically possible but does not exist in the market. Current systems available in Yangon have a negative benefit cost ratio compared to diesel pumps, primarily due to cheap fuel. The scope for Yetagon's solar systems is limited due to the topography. As low-cost solar systems begin to enter the market and if fuel prices rise, solar pumping will make financial sense in the future.

Irrigation Efficiencies

More efficient irrigation could increase irrigated land, but it is difficult to predict the extent

The application efficiency of existing furrow irrigation is unknown and could be anywhere between 10% and 70% depending on scheduling practise, soil conditions and furrow design. As such it is difficult to know what to benchmark efficiency improvements against. If irrigation efficiency is increased from 50% to 75% and yields improve 20% as a result, the net margin per m^3 of water would double; e.g. the effective 'value' of the water would double. The real gains could be more dramatic if current irrigation efficiency is less than 50%.

The number of additional acres that could be irrigated with the available water depends on both the current irrigation efficiency and the amount of 'wasted' water that already flows back into the stream for other farmers to use. If the current irrigation efficiency is 50% and 50% of unused water travels back into the stream then for every 1,000 acres of tomato or cabbage improved to 75% efficiency a further 250 acres could be grown at 75% efficiency using the 'saved' water.

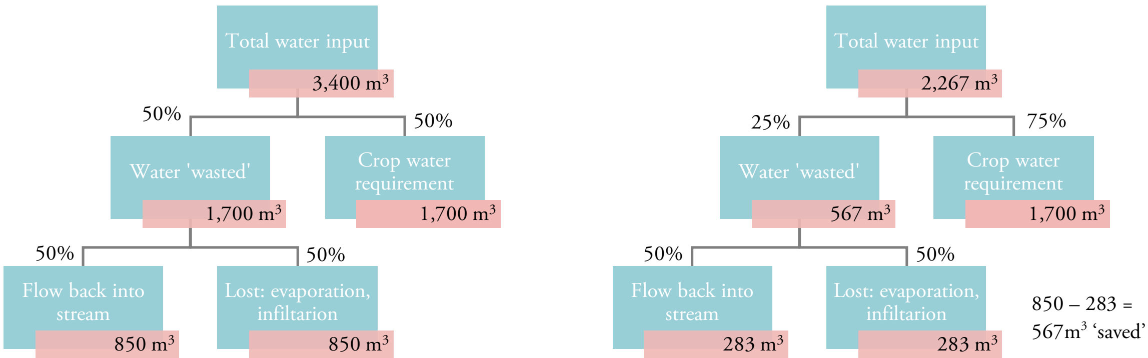


Figure 1: Water flow diagrams for 50% application efficiency (left) and 75% application efficiency (right) for 1 acre of tomato or cabbage over the full crop cycle, showing a 'saving' of 567m^3.

The benefit cost ratio of sprinkler and drip systems is not yet known

Establishing the payback period and benefit cost ratio for sprinkler and drip systems would be highly beneficial. Some data is available from other contexts but demo plot based local data could be developed. In Pinlaung farmers installed sprinkler systems to save on labour costs, with a payback period of 6 cycles. By introducing drip fertigation in Vietnam, Asia Irrigation achieved a single crop cycle benefit cost ratio of 3-to-1.

A separate review of irrigation practices would be beneficial

A separate technical review of irrigation practises would be beneficial. This could determine the water efficiencies of current furrow systems as well as analysing the impact or current scheduling and application practices.

Demo farms and village visits can trigger change

Most farmers have not seen drip irrigation in practise. Farmers mainly base their practises and choices on what they see their neighbours do. Demo plots for sprinkler and drip irrigation will help to provide awareness of correct practises, benefits and costs. There is an added value that by starting with correct practises it is less likely that farmers will incorrectly try themselves, leading to widespread bad practises and negative perceptions. Village exposure visits to farms correctly using and benefiting from sprinkler and drip at scale could help to trigger and accelerate uptake.

Natural growth in uptake requires patience and a multi-year approach

Several villages visited that currently irrigate in the off-season did not do so 5 years ago. A natural growth occurred as wealthier farmers tested pumping systems they had seen elsewhere. Other farmers waited to see at least one successful season before following suit and investing. Many other farmers were more cautious and took longer to uptake. Demo farms using sprinkler and drip systems can be the first step in this uptake process, but without accelerating factors such as access to credit natural growth will require patience and multi-year support.

Existing pumping setups can often be used with drip, but less often sprinklers

Theoretically in most cases farmers existing pumps can be used with drip irrigation systems. However, field experience from Asia Irrigation suggests that pumps are often performing well below their theoretical capacity. In order to keep initial costs down, existing pumps can be used to drip irrigate by sections, with a pump upgrade coming later. For sprinkler systems, which require more pressure, only farmers close to the water source will be able to use their existing pumps.

Irrigation efficiency subsidies would accelerate uptake

A subsidy for sprinkler or drip systems would remove a key barrier to uptake. In India, such subsidies were first used in the early 1980's. Currently the India central government provides a subsidy of 35% for drip irrigation with the States topping this up to either 50% or 100% for the poorest farmers. With the USA the government has provided substantial subsidies for improving irrigation efficiency.

In order to facilitate demo farms, subsidies for sprinkler and drip systems should be considered. These could be in the form of an expanded voucher program. Due to the relatively high cost per acre, initial demo plots for would need to be small, around 1/8th of an acre.

Irrigation guidance is limited

Currently there is no organisations or government departments providing irrigation guidance to farmers. It does not fall within the remit of the Department of Agriculture, DoI or Water Resource Utilisation Department. The crop water wheel produced by Proximity Designs is an interesting tool worth considering, although it is unclear who would take on the responsibility for outreach. The demo farms could be used to 'pass-on' information. A shared extension service between various input suppliers would be cost effective and mutually beneficial if agreement could be reached.

Other

A detailed vegetables economics assessment

A detailed vegetable economics analysis could be conducted along the same principles as the World Bank Myanmar farm economic assessment. This could be a useful tool for providing deeper evidence of the benefits of vegetable production. The study could consider the impacts of different types of irrigation, developing evidence that could be used to form higher level policy. In addition to the World Bank methodology it would be useful to have statistical analysis of risk factors and their impact on the farm economics.

Introduction

The Mercy Corps 'Making Vegetable Markets Work' (MVMW) program aims to improve the incomes of 11,250 vegetable farmers in Myanmar. It focuses on Kalaw, Pindaya, Pinlaung, Taunggyi and Nyaungshwe, five townships in South Shan. The program applies a market system development approach to work with market actors to address key farmer constraints such as access to inputs and technology, extension services, finance and markets. It seeks to help farmers to 'step-up' to more commercial vegetable production through improved farming practices and market access.

Access to water is a major constraint for farmers. The majority of farmers rely on rainfall, although a minority have access to springs, streams, ground water, retaining ponds, or other sources. Off-season production, outside of the rainy season, has the potential to unlock increased yields at higher off-season market prices. This report investigates the problem of water access for off-season production. A separate report sets out the design of possible interventions for the MVMW program to address the key barriers.

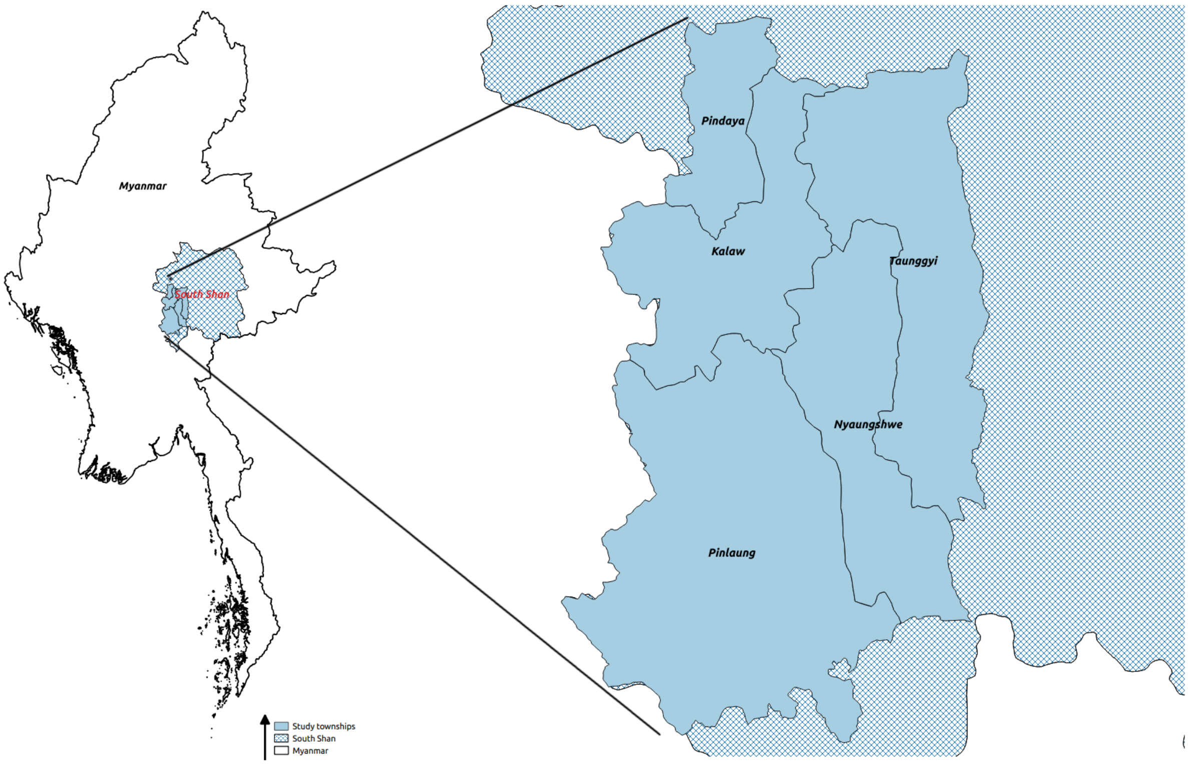


Figure 2: Area of interest. Selected five Townships of South Shan, Myanmar. Map reformatted from MIMU (MIMU, 2017).

While the scope of this report and the possible subsequent interventions are based on project level questions regarding improving water access and use efficiency, it is worth noting the global picture. It is widely believed that the world is facing both an unprecedented global water and agricultural crisis (Scheierling et al., 2014). The World Bank projects that the world population will rise by 31% to 9.7 billion by 2050. Myanmar's population is projected to rise by 9.2 million people (17%) over the same period. In order to meet the increased food demand it has been estimated that agricultural production would need to be 60 percent higher in 2050 than in 2005/2007 and global irrigation water withdrawals increase by 6% (Alexandratos et al., 2012). There is a need to expand the use of water for irrigation at a time when the water demand from other sectors is also increasing in many places. Some areas of Myanmar outside this project area, notably those with alluvial aquifers, have been shown to theoretically have capacity for additional irrigation water extraction. It was estimated that in the 3 divisions of the dry-zone of Myanmar a further 271,000 to 812,000 acres could be irrigated from groundwater (McCartney et al., 2013). We are not aware of any such analysis for the project area, which has a more complex aquifer and intricate network of springs and streams.

Notable gains can be made on improving the water productivity in agriculture. Productivity improvements, such as through improved irrigation, would likely result in higher crop production with the same amount of water, rather than the same production with less water.

Improving agricultural productivity is established in the policies of several international institutions. The FAO mentions increasing agricultural water productivity as the most important aspect for managing increased demand (Alexandratos et al., 2012). The United Nations World Water Assessment Programme recommends increasing water productivity as a way of reducing the pressure to develop new water sources (UNESCO, 2009). The World Bank's Agricultural Action Plan for 2013-15 highlighted the need to improve water productivity and sustainability, particularly in areas where the possibility of expanding irrigation is limited (World Bank, 2013). Previously, the World Water Council reported that increased water productivity should account for half of the increased demand for irrigation water by 2025 (Cosgrove et al., 2000).

Water access factors

Within the context of increasing water access for off-season vegetable farming in South Shan, there is a need to consider a range of factors beyond the primary consideration of water availability and sustainability. Secondary and tertiary factors also need to align in order for a farmer to be able to improve their water access.

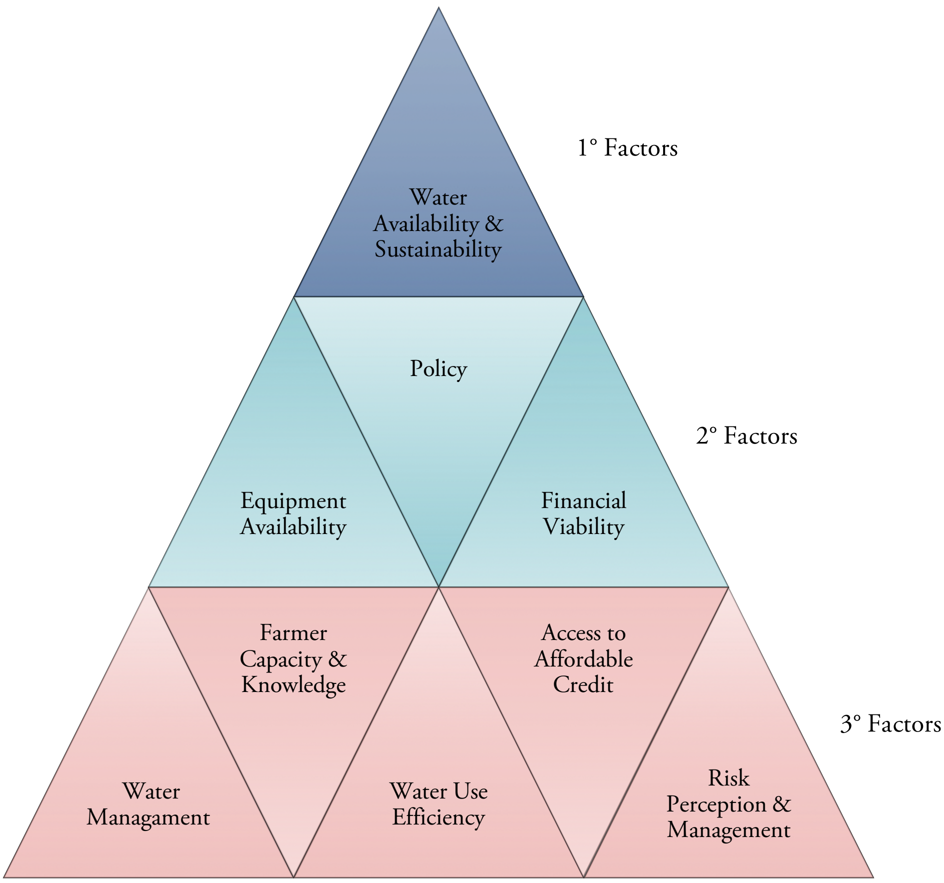


Figure 3: Water access factors for off-season irrigation. (Author)

Available water must be financially viable to access and use, the technology and equipment to do so should be available in the local markets and the policy environment should be conducive rather than limiting. Beyond these secondary factors, which ensure that it is theoretically possible to access the available water, are a range of tertiary considerations which can further limit the farmer's theoretical ability to access water. These include the farmer's capacity and knowledge; do they know how to access the water, what equipment they would need, how much it would cost and what the financial benefits could be? Do they have the required cash or can they access affordable credit? Are there systems in place to manage the water at the individual, community or basin level? How efficient will water usage be, how much will be lost and do the wider factors create an environment where farmers are willing to take a potential investment risk? This report aims to cover each of these water access factors and identify the primary barriers to increasing water access.

It should be noted that the scope of this report focuses on increasing water access and efficiencies from an environmental, behavioural and markets perspective and does not set out to investigate detailed irrigation practises, efficiencies and scheduling.

Methodology

This analysis and the subsequent 'MVMW intervention report' were commissioned through a 25-day consultancy project. The main components of the methodology were as follows.

Field Work

Field team meeting

Carried out on January 5th at the Mercy Corps Aung Ban office in order to get the perspectives and inputs of the field team, which included the intervention manager, field team leader, township business management officers (BMO's) and the local Asiatech distributor. This was considered an important first step to help frame the direction of the subsequent field visits given the time frame.

Government meetings

The following government departments were met with in the field:

i. The Department for Rural Development (DRD), South Shan state level, were met on 19th January in Taunggyi. While only created 3 years ago the department has experience of finding and developing spring sources for rural domestic use and prospecting groundwater.
ii. The Department of Irrigation (DoI), South Shan state level, were also met on 19th January in Taunggyi. They are responsible for formal irrigation schemes such as dams and canal systems.
iii. The Department of Agriculture (DoA), South Shan State and Taunggyi Township level were met separately, both on 20th January in Taunggyi. While the DoA is not directly involved in irrigation projects they are key informants for the extent of irrigated areas, government perceptions of the potential to increase irrigation and the use of sprinkler and drip systems. Taunggyi township DoA were able to provide data regarding the extent of irrigated areas based on the acres of crops grown in the past year, compiled by the Land Records Department.
iv. The Water Resources Utilisation Department (WRUD), South Shan State level were met in Shwenyaung on 27th January. The WRUD are responsible for monitoring all water resources and collecting hydrogeological data for compiling by the Naypyitaw level groundwater resources division. In other areas of Myanmar they drill tubewells and manage pumping schemes from rivers for irrigation purposes.

Field village visits and FGD's

In total twelve villages were visited during the field trip. Within each of the five townships the Mercy Corps staff selected two villages meeting the criteria of having some existing access to off-season irrigation water. A third village without access to irrigation water was identified and visited if there was sufficient time, which was possible in Kalaw and Pinlaung. Therefore, it is important to note when reading this report that the villages visited do not represent a random sample. Had a random sampling method been used it is likely that more than 70% of the villages visited would have no access to an irrigation water source, limiting the usefulness to the goals of this study.

Within each village a focus group of five to ten farmers was requested. The selection of specific farmers was not restricted and could be selected by the village focal point. As such the attendees related primarily to their availability on the date and time of the pre-arranged meeting. Each discussion followed a set of pre-arranged questions and took between 45 to 75 minutes, after which visits were conducted to visually assess the water points, pumping equipment, land irrigated, irrigation methods and crops grown. More specific targeted questions were asked based on what was observed to develop a deeper understanding.

With the field visits being conducted during the middle of the off-season it was possible to see directly the situation in regards to irrigation. With many water sources reducing around March, many areas are not able to grow a second off-season crop after January, making the timing of these visits almost ideal as they generally showed the maximum possible extent of first off-season crop. In around half the villages visited the FGD participants omitted some smaller private irrigation water sources, it is presumed unintentionally. The field walks were able to identify such omissions.

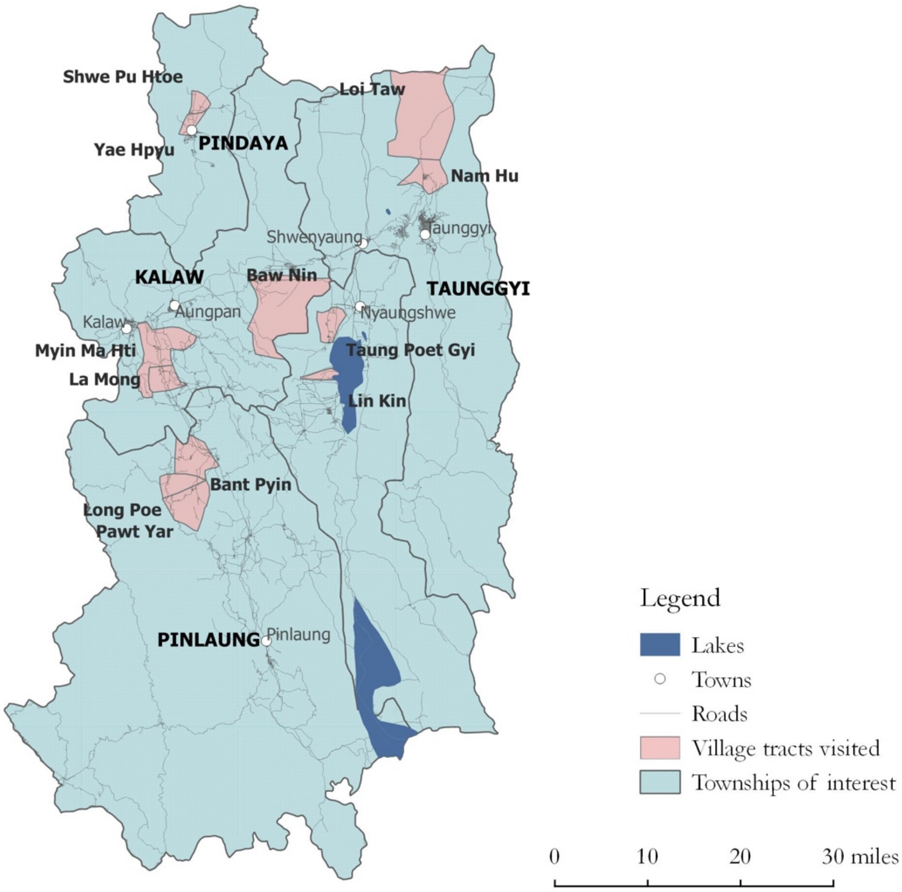


Figure 4: Map of area of interest highlighting village tracts visited during the field trip. Map by author using map files from MIMU (MIMU, 2017).

	Date	Township	Village Tract	Village	Male	Female
1	6th January	Kalaw	Baw ninn	Chaung Ni Pauk	4	-
2	25th January	Kalaw	Myin Ma Hti	Nang Ong Ywar Ma	7	-
3	25th January	Kalaw	La Mon	Baw Di Kone	7	1
4	23rd January	Taunggyi	Nan Hu	Pin Lon	8	4
5	23rd January	Taunggyi	Loi Kaw	Hti An	3	6
6	24th January	Nyaungshwe	Taung Poet Gyi	Taung Poet Gyi	5	1
7	24th January	Nyaungshwe	Lin Kin	Taung Gyar Taung Gyar	9	-
8	26th January	Pinlaung	Pan Pyin	Naung Lin	8	-
9	26th January	Pinlaung	Pawt Yar	Inn Gaung	6	-
10	26th January	Pinlaung	Long Poe	Long Poe	4	-
11	27th January	Pindaya	Yae Phyu	Zaw Gyi	7	-
12	27th January	Pindaya	Shwe Pa Htoe	Htoe Pon	6	-
					Total = 86	

Table 1: Villages visited during the field work and the number of male and female participants in FGD's.

Private sector contractors

Borehole drilling contractors were contacted in Taunggyi and Aung Ban areas, identified through field team contacts and DRD recommendations. Of the three contacted it was possible to meet one from Taunggyi and one from Aung Ban. It was hoped that given the lack of hydrogeological data that it may be possible to obtain some records and recommendations. In both cases, no formal drilling records were kept but anecdotal feedback was obtained.

Private sector suppliers

Suppliers of pumping and irrigation equipment were met in Taunggyi, Shwenyaung and Aung Ban in order to (i) confirm the prices of equipment for the cost benefit analysis, (ii) get insights into the popularity of different items, (iii) understand how farmers select between different models and (iv) explore any formal or informal credit systems. The following suppliers were visited or contacted.

Date	Supplier Location	Supplier Name	Relevant Products
18th January	Asia Region	Asia Irrigation – Bruce Cussen	Drip irrigation (telephone interview)
19th January	Taunggyi	SMM	Engines, Pumps, Pipes
19th January	Taunggyi	'unknown'	Yetagon products
20th January	Taunggyi	Royal Myanmar Trading	Engines, Pumps, Pipes
20th January	Shwenyaung	Good Brothers	Engines, Pumps, Pipes
20th January	Heho	'unknown'	Engines, Pumps, Pipes, Yetagon products
28th January	Aung Ban	Forever	PVC pipes and sprinkler heads
28th January	Aung Ban	'unknown'	PVC pipes and sprinkler heads
28th January	Aung Ban	Daewoo Electronic	Solar panels
28th January	Aung Ban	'unknown'	Yetagon products (telephone interview as no physical shop premises)

Groundwater data

Due to a lack of available groundwater information from the state level DRD, WRUD and local contractors, the following organisations were met in Yangon. These meetings confirmed that no further information is available in Yangon. The main source of potential further information is considered to be the groundwater section of the WRUD located in Naypyitaw, a visit to which was beyond the scope of this assessment.

Date	Location	Organisation
2nd February	Yangon	Geology Department, Yangon University
2nd February	Yangon	Unicef WASH
2nd February	Yangon	Resource & Environment Myanmar
2nd February	Yangon	Myanmar Environment Institute

Desk study

Groundwater analysis

Given the lack of available hydrogeological data for the area of interest Google Scholar was searched for the terms 'Myanmar/Burma Geology', 'Myanmar/Burma Hydrogeology', 'Shan plateau' and 'Inle lake'. The limited books or articles found were downloaded via the authors Open Athens login. GIS data which could inform the study was gathered from the HydroSHEDS project, 'Myanmar Agricultural Atlas' and base administrative files from MIMU ("HydroSHEDS," n.d.)(FAO, 2005)(MIMU, 2017). Additional maps were sourced and provided by 'Ground Water Relief' (GWR, 2017).

Extent of streams

With the main source of irrigation water being from small streams an exercise was conducted to analyse their extent. Existing GIS data from MIMU covers only major rivers and water bodies and data from HydroSHEDS, although more detailed, did not capture the small streams encountered during the field visits and was found to have other errors when compared to recent Google satellite imagery. Remote automated analysis of streams was not possible due to free satellite imagery, such as through Landsat, having an insufficient resolution to identify these streams which are often only a few meters wide during the off-season (EarthExplorer, 2017). Automated predictive analysis using digital elevation models was also viewed as not appropriate given that most the streams start as springs. Google satellite imagery is the highest resolution free data available.

Therefore, a manual digitising method was conducted for the 9,500 km^2 area to create the hydrology layer. The main data source was Google Satellite image mosaics. Across the study area 90% was covered by images from 2015-16, with the remaineder from 2012/14. The method involves manual tracing of visible stream lines. In order to cross check and verify the new layer additional inspection was carried out using satellite images from Sentinel-2, digital elevation models from Aster, HydroSHEDs and Google street maps. Stream boundaries of 500, 1000, 1500, 2000, 2500 and 3000 feet were then automatically created and used to compare and overlay with the map of irrigated areas. In total this exercise required around 40 hours of work and was carried out by freelance GIS technician Roman Perkhaliuk, based in Ukraine.

The resulting map cannot be assumed to be entirely accurate as a level of prediction and reasonable assumption was required when trying to trace streams which are often so small that only the meandering tree lines are visible. In most cases the tree lines obscure any view of water and as such it was not possible to verify which streams are dry in the off-season. However, it provides significantly more detail as compared to any previously available data. The map files are available with Mercy Corps.

Extent of Irrigation

In order to gather more insight and analysis into the current extent and location of off-season irrigation a remote sensing desk study analysis was conducted. GIS expert Dr. Sajid Pareeth, who holds a PhD in remote sensing and is based in Rome, was commissioned to carry out this work. Cloud free images from Landsat data (15-30m Pixel) were combined with multi-temporal MODIS data (250 m pixel) and analysed for the period December to April using an established irrigation extent algorithm to identify cropping patterns based on vegetation greening and senescence, represented using NDVI and Landsat to provide better spatial definition. Further details are provided in Annex A.

Cost benefit analysis

In order to develop the cost benefit analysis data was gathered regarding the varying input costs and sale costs. Sale costs were provided by the Mercy Corps monitoring and evaluation (M&E) team, which track the selling prices for farmers in South Shan on a monthly basis as well as in the farmer baselines. Data regarding crop yields was obtained through the farmer baseline, East West Seed and the agricultural sector review (FAO, 2004a).

Obtaining accurate data regarding input costs for common vegetable crops was particularly challenging. The Mercy Corps farmer baseline contains data regarding crops grown, area and input costs. However, there was significant variation. Similar large variation in costs and returns were found during a recent study in the dry-zone of Myanmar (Senaratna Sellamuttu et al., 2013).

The resulting analysis assessed the length of the payback period, in crop cycles, of investments to increase water access and the 20-year benefit cost ratio.

Water Availability and Sustainability

This chapter explores the environmental availability and sustainability of water for irrigation use. We look at the current situation including the main sources of existing water, primarily springs and streams. Groundwater is not widely utilised but we analyse the available data and conclude that it could be further exploited. However, there are key barriers around awareness, risk and access to credit that would need to be overcome.

This report is focused on the off-season growing of vegetable crops. Most farmers are able to cultivate their land during the rainy season which runs from May to mid-November. The off-season is considered from mid-November to April, during which time there is almost no rainfall as shown in the figure below.

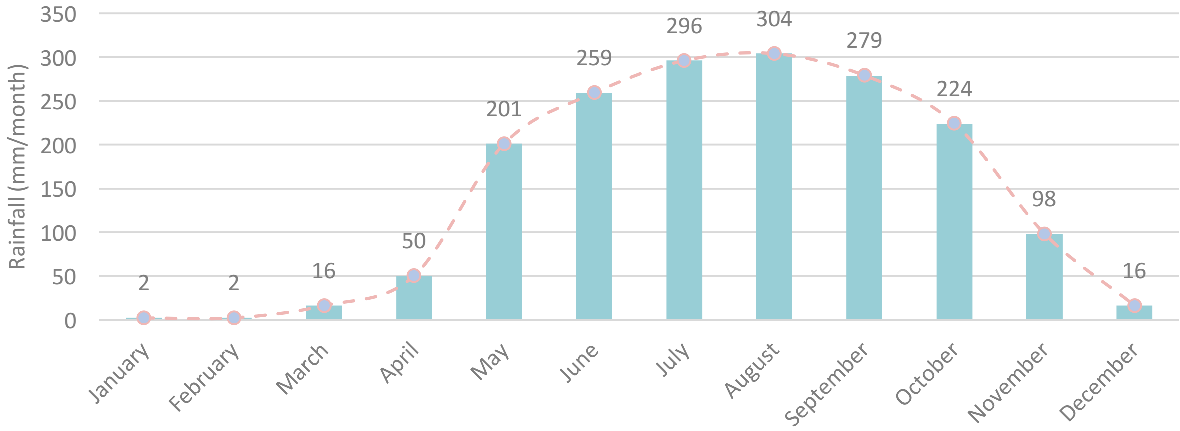


Figure 5: Rainfall in project area from Taunggyi data station. Source: (FAO CLIMWAT)

The majority of rural communities rely on natural springs for drinking and irrigation water, either directly at the source or downstream from the streams that they form. Groundwater is generally deep (200-700ft) and is not widely utilised for either domestic uses or irrigation, primarily due to the more widespread availability of natural springs. In some areas farmers have found shallow groundwater (<30ft) which they are able to access through self-made dug-wells or low-cost tubewells. There are some cases of small scale dam projects, but their reach is limited. No cases of rainwater harvesting for irrigation were found and it is a rare source of drinking water.

Of the twelve villages visited all presented a different water availability situations highlighting both the micro and macro level heterogeneity of the region.

The majority of areas do not have sufficient current water resources to be able to irrigate in the off-season. Across South Shan six percent of people do not have a water source within thirty minutes walking distance and domestic pipelines from springs can be required to extend over four miles (MoNPED et al., 2011). The Mercy Corps field workers estimate from their experience that only between 10 and 40% of villages in a township have access to some form of water which can be used for off-season irrigation.

Villages with access to some irrigation water source	Can Irrigate	Can Not Irrigate
Pinlaung	25 %	75 %
Pindaya	20 %	80 %
Taunggyi	15 %	85 %
Kalaw	10 %	90 %
Nyaungshwe	40 %	60 %

Table 2: Mercy Corps field staff perceptions of the percentage of villages in each township which have access to some form water which can be used for off-season irrigation.

Data from the Mercy Corps MVMW baseline study shows a more favourable water access situation but is not considered representative of the overall five townships and situation. This is due to lowland and irrigated areas being more suitable for the MVMW program. The field staff perceptions are considered more representative as they more closely match with other data presented in the irrigation extent chapter.

Drinking Water

It had been expected that a larger proportion of irrigation water would come from groundwater based on the latest national drinking water source data, the 2010 multiple indicator cluster survey. During the field visits no villages were using protected wells, with the majority using piped supplies from springs. The Department for Rural Development (DRD) stated that around 70% of people in South Shan rely on Springs, around 20% on tubewells and the remainder dug wells and rain water harvesting. Rainwater harvesting ponds are not common and only constructed by the DRD if no practicable spring or groundwater can be identified.

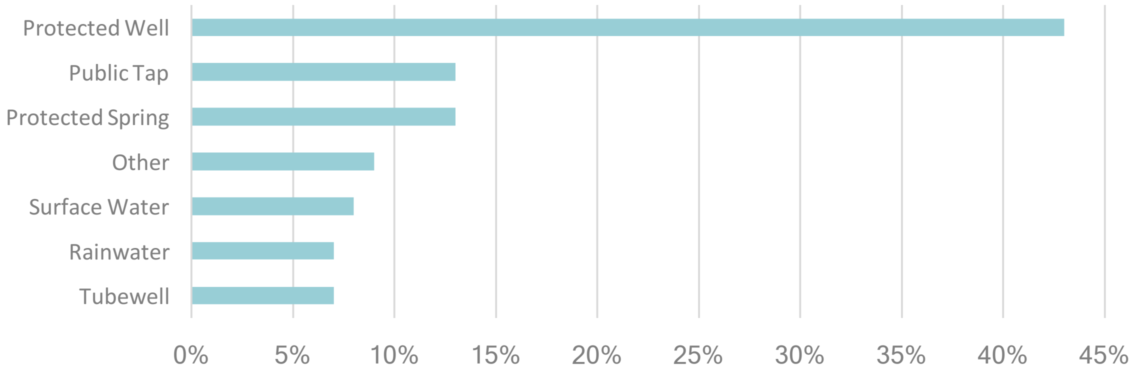


Figure 6: Drinking water sources in South Shan.(MoNPED et al., 2011). Note that field visits and the DRD meeting contradict this data.

The DRD stated that during the previous dry-season only 5 of 372 villages reported water shortages and made requests for additional water.

In three of the twelve villages visited the main drinking water source was also used for irrigation. In all cases, the allocation of water to irrigation was conservative with domestic use the clear priority.

Hydrological basins

The project areas fall primarily within the Thanlwin basin with some of the western parts of Pindaya, Kalaw and Pinlaung within the Ayeyarwady basin.

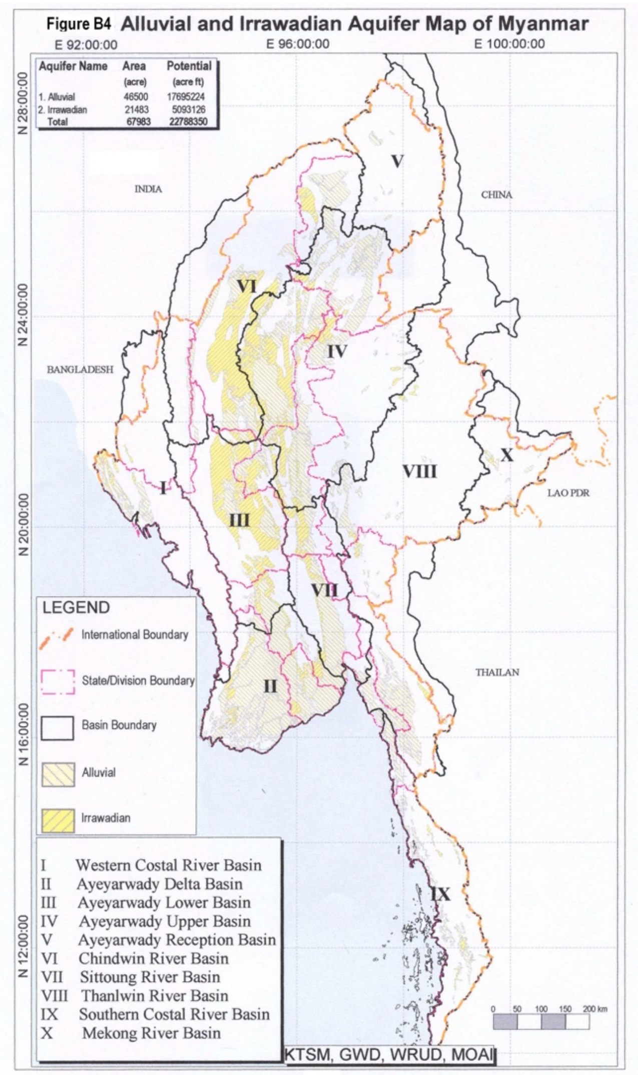


Figure 7: Alluvial and Irrawaddian aquifer map of Myanmar (FAO, 2004b).

Geographic information system (GIS) data was downloaded from the global HydroSHEDS project and overlaid on the project area to assess the size and range of local level hydrological basins. The figure below shows the most detailed level of data available. Each shape represents an individual hydrological basin, within which upstream uses will directly affect downstream users. It can be seen how multiple villages share basins. What this map cannot show is the subsequent relationship between these basins. It would be theoretically possible to colour code each basin based on their position up or downstream. This would give a visual indication of which areas are likely to have the 'priority' in accessing off season water.

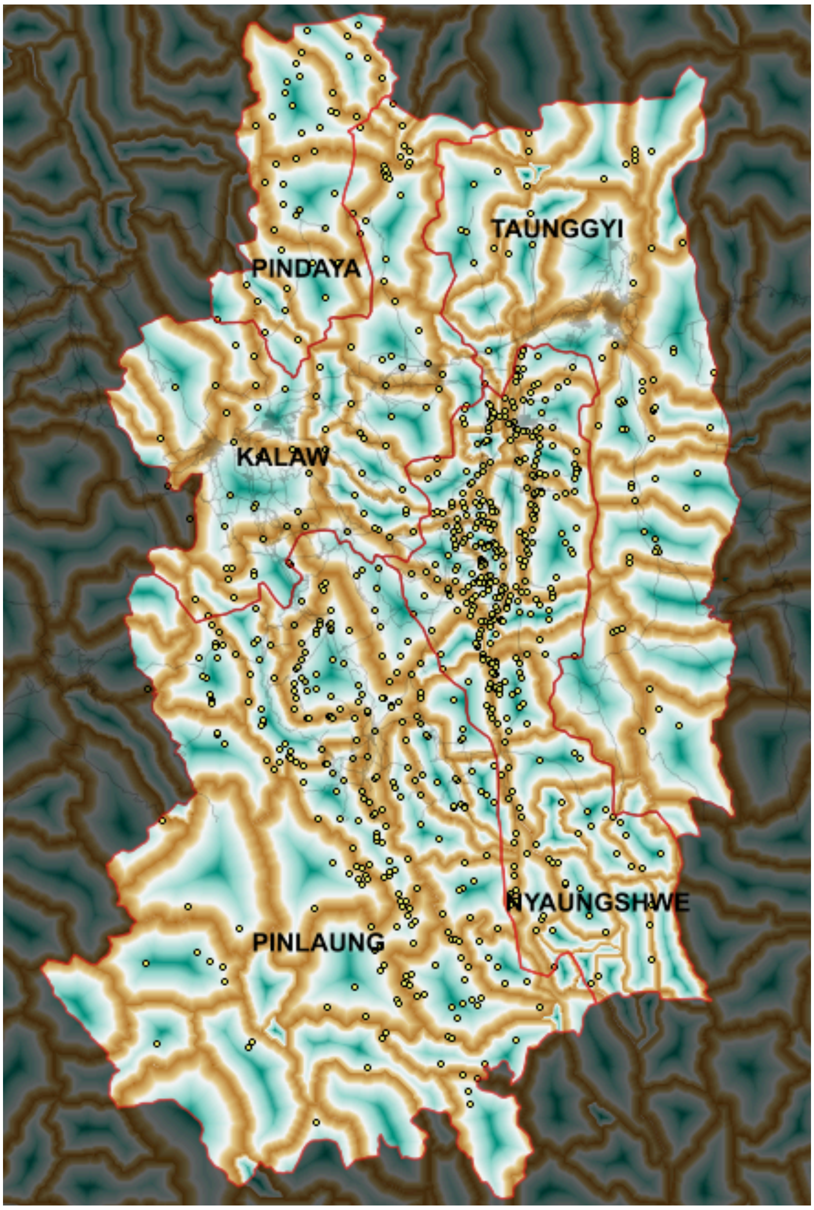


Figure : Hydrogeological basins in the area of interest. Villages shown as yellow dots. Township boundaries in red. Created by author based on data from ("HydroSHEDS," n.d.),(MIMU, 2017)

Natural Springs and Streams

Natural springs and the streams that they form constitute the main source of both domestic and irrigation water. As such the majority of irrigated areas are within 1,000 to 2,000ft of streams, with the most upstream villages having priority for use.

Figure 8: Kalaw Township, Ong Ywar Ma village. Shallow natural spring with numerous spring holes under and around the pond, created by a DRD built dam which overflows into a steam.

Figure 9: Pinlaung township, Naung Lin village. Shallow natural spring with numerous spring holes under the pond, created by a DRD built dam. There are around 10 similar ponds in this village as well as shallow dug wells.

Figure 10: (Top) Taunggyi township, Pin Lon village. Shallow natural spring pond dug by farmers using a back hoe at a cost of 400,000 MMK ($320). (Bottom left) Spring holes as seen through the water, roughly 5ft below the surface. (Bottom right) The locally known "water rock". When found in their field farmers are confident that there will be a shallow spring in the immediate area.

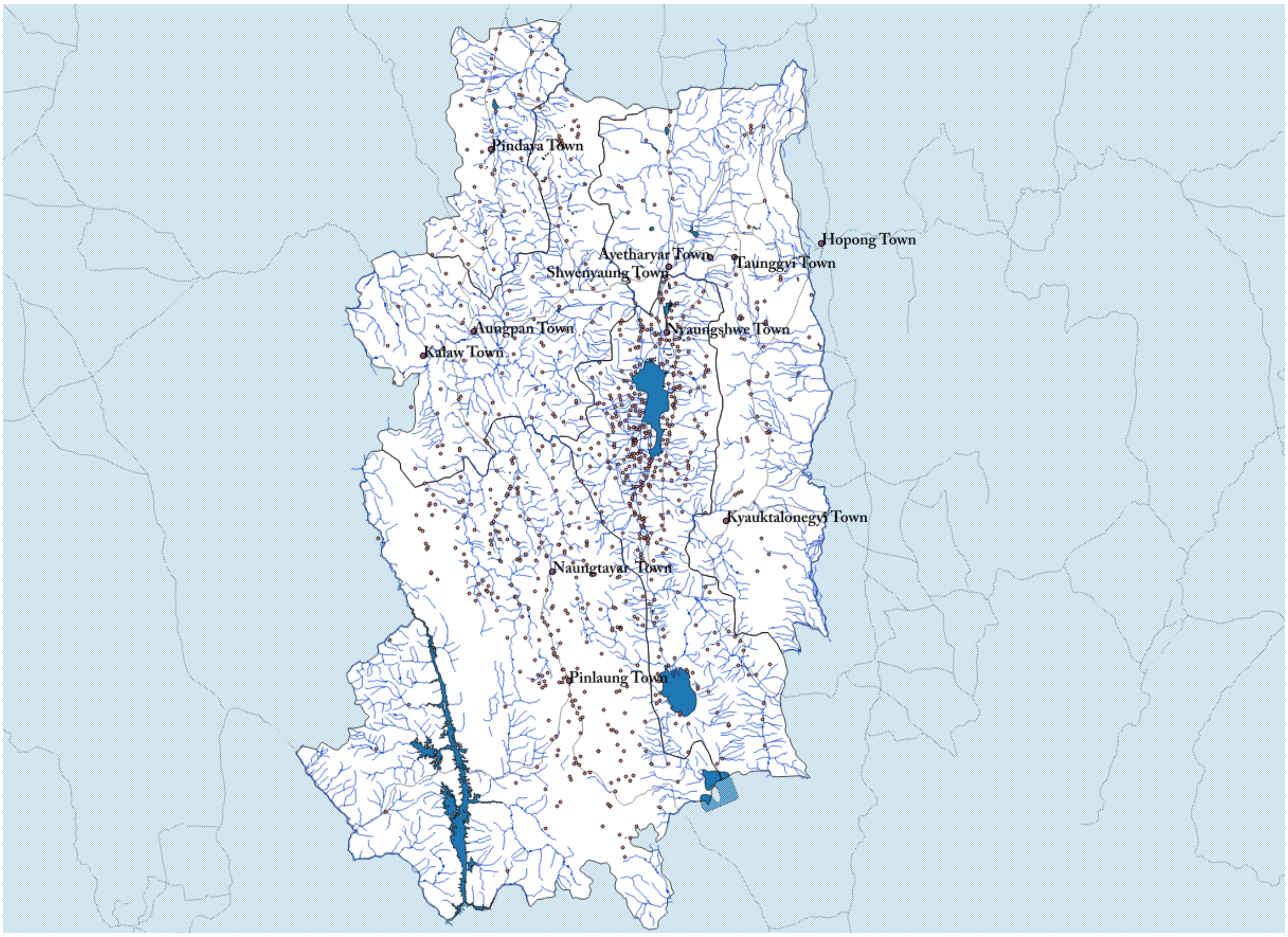


Figure 11: Rivers, streams, lakes and villages in area of interest.

The DRD suggested that in general, small-scale dams that support local irrigation have already been constructed in most known feasible areas.

Increasing extractions from streams is the simplest way to increase water usage where the quantity is sufficient. However, underutilization by upstream farmers can result in availability for farmers downstream. This could be investigated further by monitoring water flows at various points along the stream over the course of at least one year.

New springs could be available, but there is no easy way to identify where they may be. In many areas, the DRD have already conducted searches for the purpose of domestic water.

Rainwater harvesting and small ponds

No cases of rainwater harvesting for irrigation were identified in the project area, although they are a common source of drinking and sometimes used for small scale irrigation in the dry zone and delta areas of Myanmar. In the areas that they are used there is often a lack of community-led maintenance and a need for external programs to sustain full functionailty.

In the Asia region, India has around 200,000 small reservoirs (tanks) which irrigate around 5.5 million acres and tank irrigation is the predominant form of irrigation in Sri Lanka. However it is worth noting that tank irrigation in India declined by 32% between 2001 and 2008 due to maintenance and repair issues (Palanisami et al., 2010).

Geology

The geology of Myanmar is intimately connected with the tectonic activities that have resulted from the Indian Plate colliding and being subducted under the Eurasian plate. The rocks within South Shan are complexly faulted and folded and these structures have formed rugged ranges generally striking north to south.

An overview of key structures running through Myanmar is shown in Figure 12.

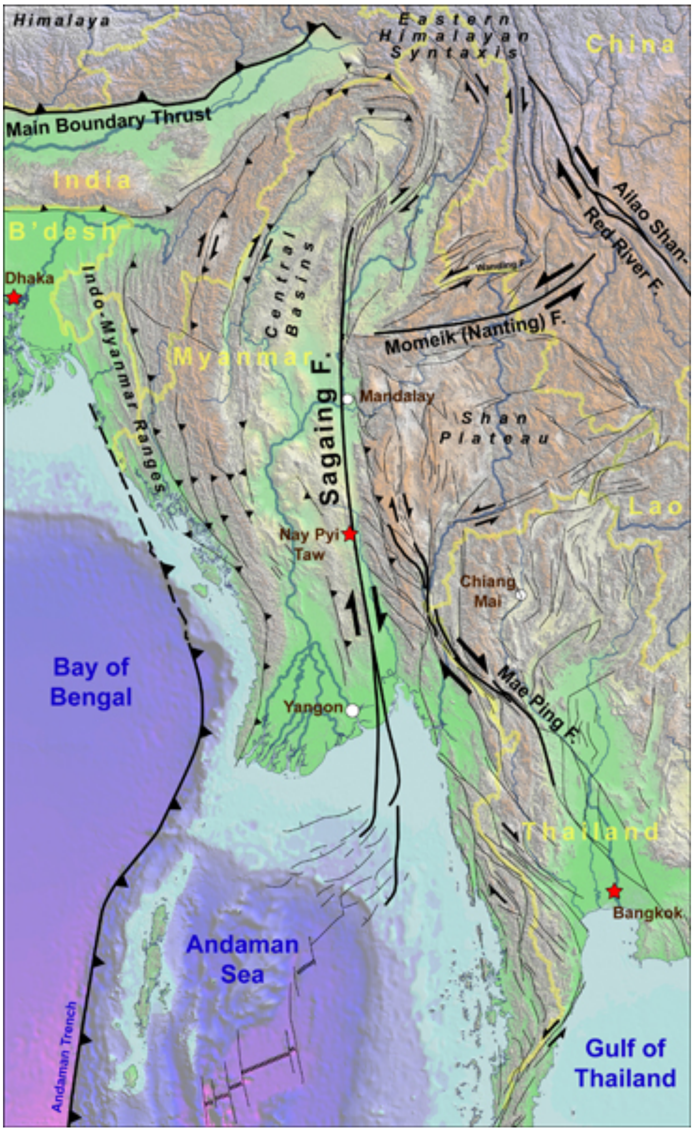
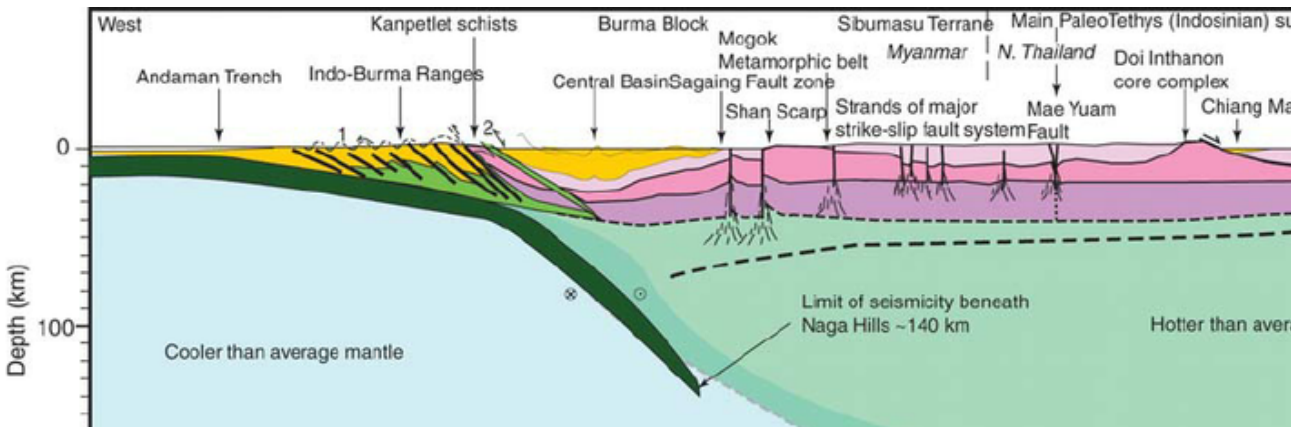


Figure 12: (left) Overview of Myanmar key geological structure

Figure 13: (below) Geological cross-section of Myanmar



Within South Shan, the rocks become progressively older as you go eastwards, with Jurassic aged Kalaw red beds and Loi-an Series outcropping to the east of the study area, Permian and Devonian aged Limestones outcropping in the centre of the study area, followed by Ordovician and lower Paleozoic aged rocks outcropping to the east and west of the Inle valley.

Table 3 provides a description of the main geological units found within the study area and a geological map is provided below.

Formation	Age	Description
Alluvium	Quaternary	Fluvial and lacustrine deposits of clay, silts, sands and gravels
Irrawaddy Group	Miocene-Pliocene	Yellow to brownish coarse cross-bedded sandstones with interstratified ferruginous conglomerates, claystones, hardened fine sandstones and red soil horizons.
Kalaw Red Beds	Jurassic-Cretaceous	Units of red siltstones and conglomerates (Tukey, 1973)
Loi-an Series	Jurassic	Well bedded sandstone mudstone turbidites
Plateau Limestone	Permian	various limestone and dolomite units bearing abundant coral remains[1]
Pindaya Group	Ordovician	Thick-bedded, burrowed, pelletal or silty limestones with irregular silt specks or laminae, and the grey or yellow siltstones (Tukey, 1973)
Undifferentiated Paleozoic Sediments	Middle to Lower Paleozoic	Possibly associated with the Molohein group: pinkish, purplish or reddish brown, highly micaceous, and very slightly regionally metamorphosed sandstones, and granular or well recrystallised quartzites of white, pinkish white or purplish white color. Subgreywacke, gritty sandstones, phyllites, dolomites, limestones and conglomerates are minor units (Thein, 1973)

Table 3: Main geological units within the study area

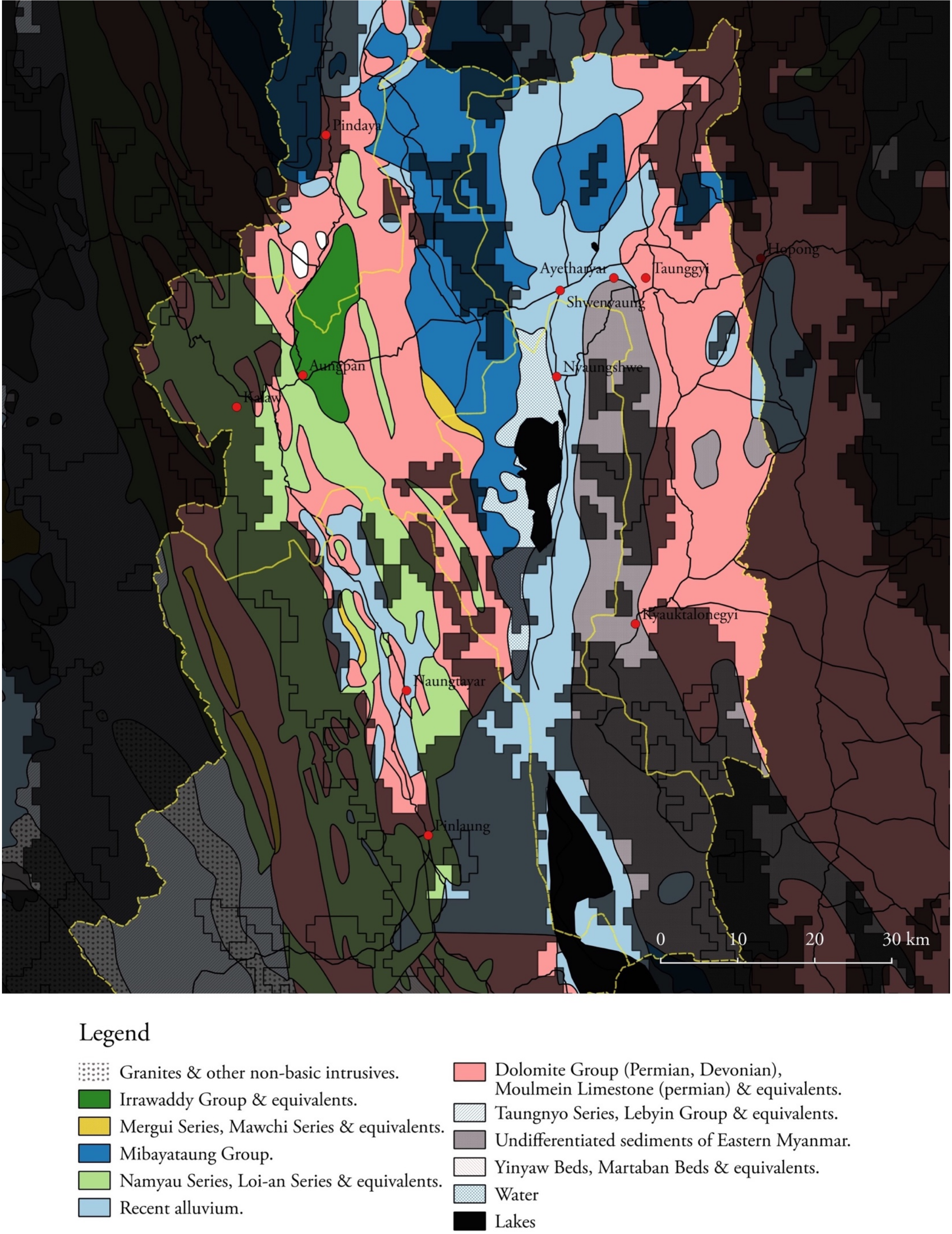


Figure 14: Latest geological map of townships of interest, produced by Myanmar Geosciences Society, accessed in Myanmar Agricultural Atlas (FAO, 2005). Areas representing deciduous forest, evergreen forest and scrubland are greyed out in order to highlight the geology in main agricultural areas of interest, land use data produced by UNEP (2000), accessed in MIMU GIS resources (MIMU, 2017).

In the centre of the study area is the Kyaukkyan fault zone which forms a trough infilled with recent alluvium deposits. The Inle Lake sits within this fault zone.

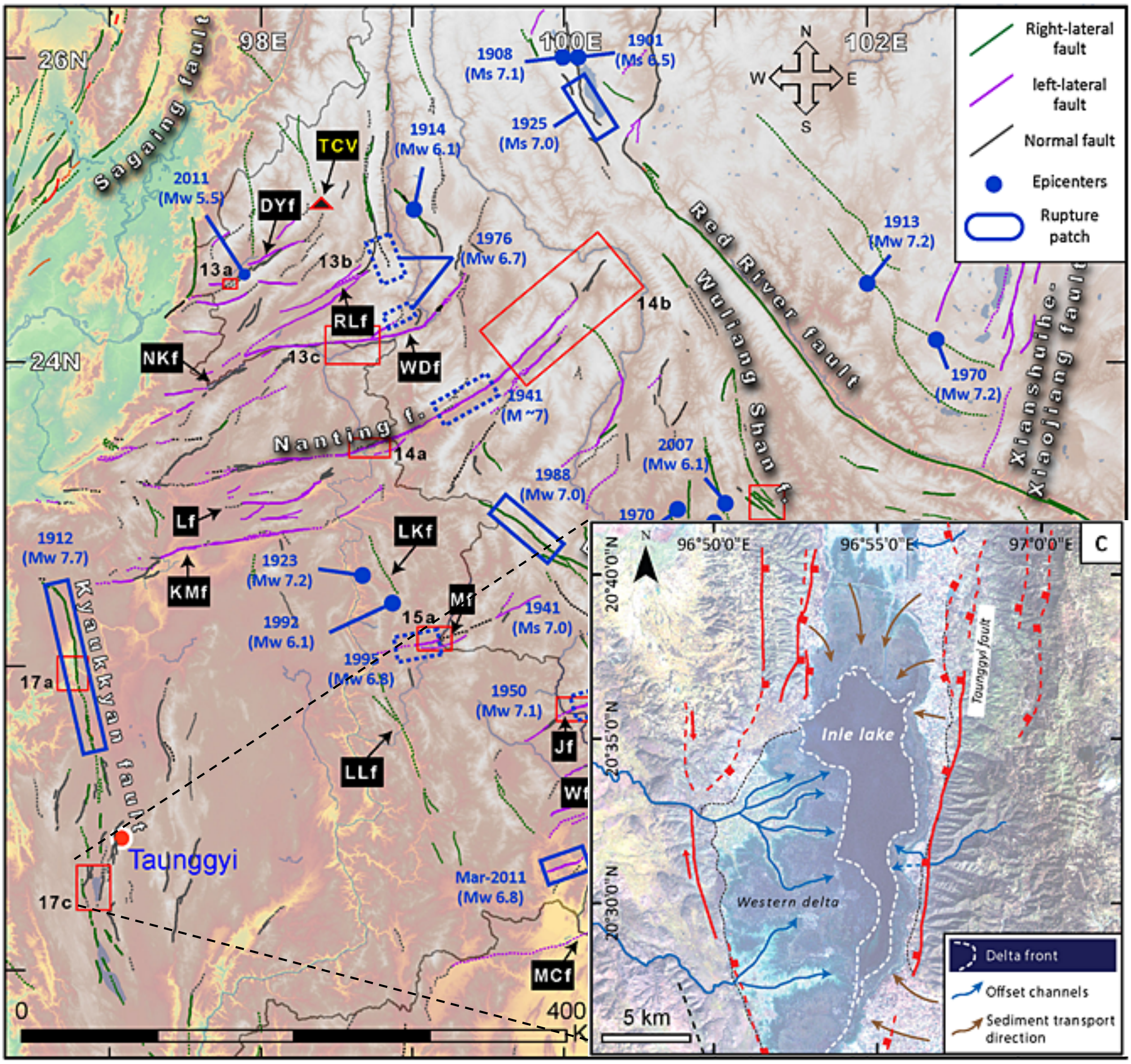


Figure 15: Fault zones within area of interest

Groundwater

Groundwater is not widely utilised for either domestic uses or irrigation, primarily due to more widespread availability of natural springs. The Department of Irrigation (DoI) and WRUD do not drill boreholes for irrigation purposes as it is considered too deep and the flowrates too low. The State WRUD considers groundwater suitable for irrigation in situations where the drilling depth and water level are shallower, the plot size is small and drip irrigation can be utilised.

Data Availability

The groundwater division of the WRUD compiles groundwater data for Myanmar. When approached for hydrogeological information the WRUD advised that hydrogeological maps for South Shan do not currently exist but will be created in 2017 based on borehole drilling logs, which are in the process of being digitalised and are not currently available.

An example of the data that will be available in the future was shared for Taunggyi town.

The Department for Rural Development (DRD), which is responsible for small scale rural domestic supplies, engages local contractors to construct tubewells. They informed that borehole drilling records are not requested or kept for this work, although a local contractor reported that they have been required to provide such records to the DRD since the beginning of 2016.

Two local drilling contractors in Taunggyi and Aung Ban were visited. Both contractors do not keep borehole drilling logs.

UNICEF Yangon have some basic data from DRD, which could not be shared, but do not yet have any data from the groundwater division of the WRUD.

With the lack of the usual data sources the only available information to make broad analysis is:

1. Anecdotal information provided by two drilling contractors.
2. Opinions shared by the WRUD and DRD.
3. A list of boreholes drilled by WRUD within the past 3 years in the area of interest, including data on drilled depth, water strike depth, static water level and yield. Locations are stated but not able to be transposed onto maps.
4. An example borehole drilling log report for Taunggyi town provided by WRUD.
5. Anecdotal information provided by farmers across the eleven villages visited.

If the planned WRUD database and hydrogeological maps are completed in 2017, a further more accurate analysis can be conducted.

WRUD Data

The following table shows the details of boreholes drilled by WRUD between 2014 to 2016 across the five project townships. Location descriptions are provided but not in a format that can be transposed onto a map without detailed local knowledge. It is thought that most boreholes were drilled in Taunggyi due to the requirements of private donors funding WRUD.

According to the drilling data provided by WRUD there appears to be a significant amount of heterogeneity in the underlying deposits with considerable variation in drilling depth and no correlation between depth and yield.

A lack of good quality drilling records means that developing a good understanding of the aquifer systems within South Shan is currently not possible.

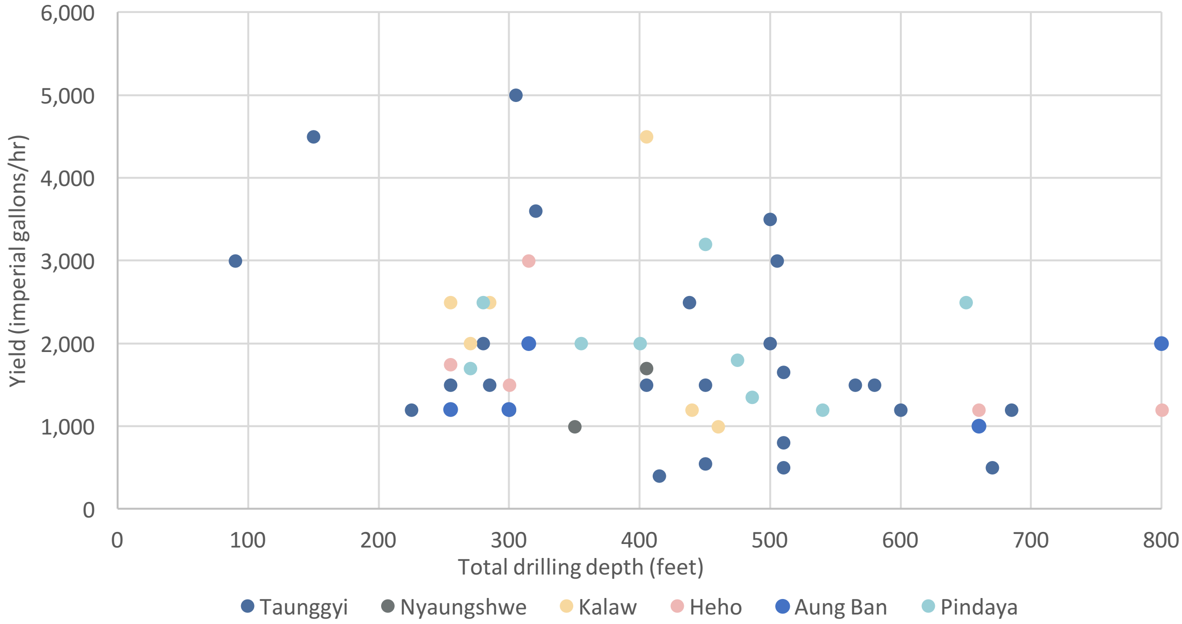


Figure 16: Basic data provided by WRUD showing the depth and yield of successful boreholes across the area of interest in the past 3 years

Anecdotal hydrogeological information

Two contractors were interviewed, one in Taunggyi suggested by DRD and the other in Aung Ban. Neither contractor kept drilling log records. Both contractors reported that they were rarely contracted by farmers, most of their work comes from the government for domestic projects. The local contractors are able to drill up to 350ft. For deeper boreholes only the WRUD has the required drilling rigs and equipment.

They bid for contracts based on their local knowledge, experience and prospecting with dowsing rods. An attempt was made to transpose this local knowledge onto a map, however this proved unsuccessful due to the drillers unfamiliarity with mapping.

The Taunggyi contractor reported information on drilling in Taunggyi and Shwenyaung localities. The Aung Ban contractor reported information on drilling in Pindaya, Pinlaung, Taunggyi, Heho, Nyaungshwe and Shwenyaung localities. These locations are shown on the figure below and compared against the mapped geology.

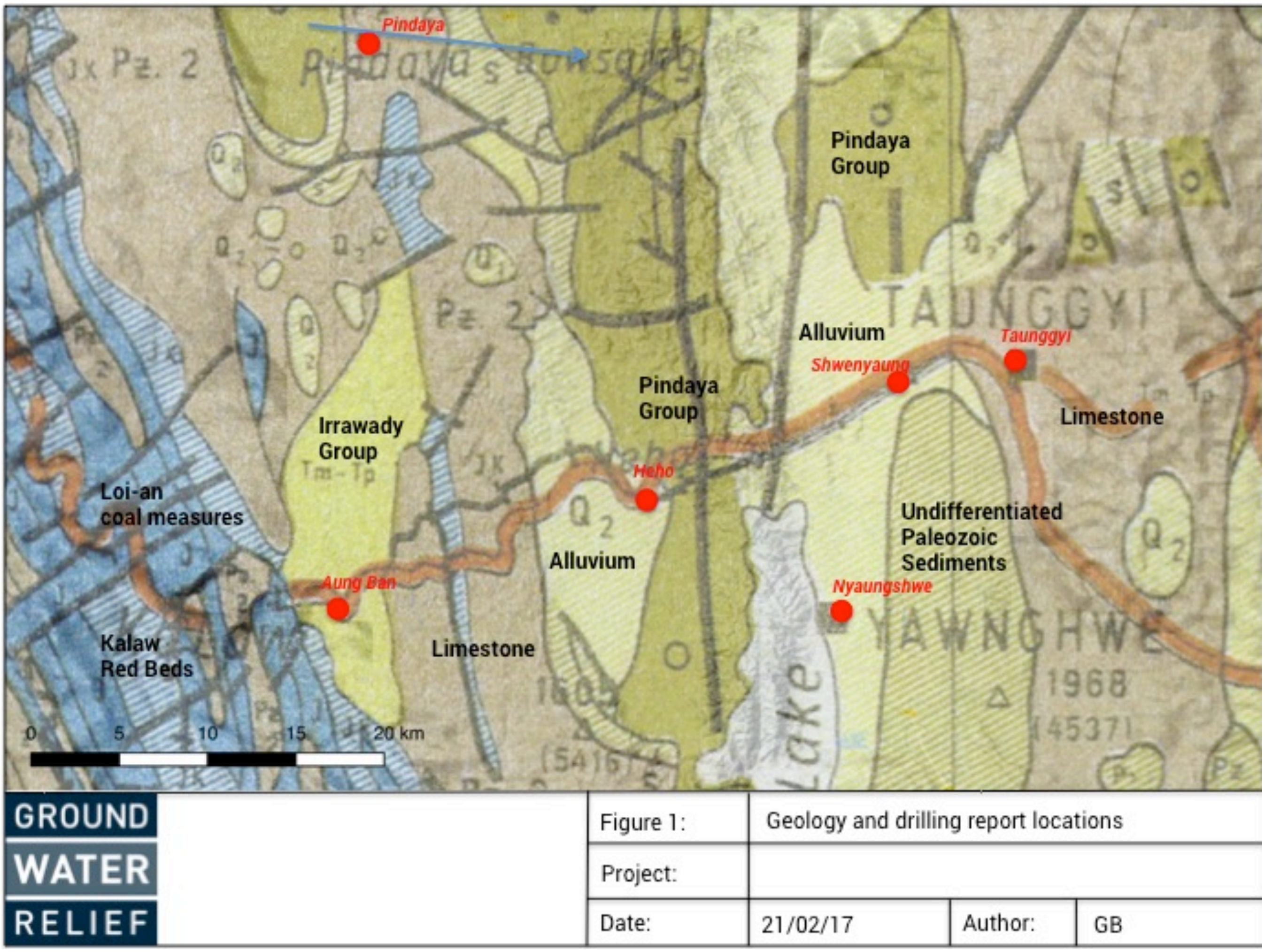


Figure 17: Geology in area of interest. Provided by Ground Water Relief for this project.

Taunggyi Contractor

The Taunggyi contractor, who has ten years of drilling experience in the area, reported that ground conditions in and around Taunggyi are fairly similar. Normal drilling depths are around 100m (328 ft), although in some areas of Shwenyaung good groundwater resources occur between 30 to 45m depth (98 to 148 ft).

The company does not normally accept drilling contracts in areas that are known to be rocky, for example in the Pindaya area.

The general conditions around Taunggyi were summarised as follows:

From	To	Description
0 ft	98 ft	Clayey soil, like surface, red or light yellow. Sometimes brown band at bottom of layer.
98 ft	148 ft	Clay, sticky, some course sand
148 ft	344 ft	Clay with bands of course sand.
Drilling stopped when desired yield is achieved, otherwise continue to maximum of 344 ft (105m).		

This information contradicts the geological map data, which shows Taunggyi to lie on top of a limestone plateau. The information also contradicts the data provided by WRUD showing the location of successful boreholes they have drilled in Taunggyi town and the simplified drilling logs.

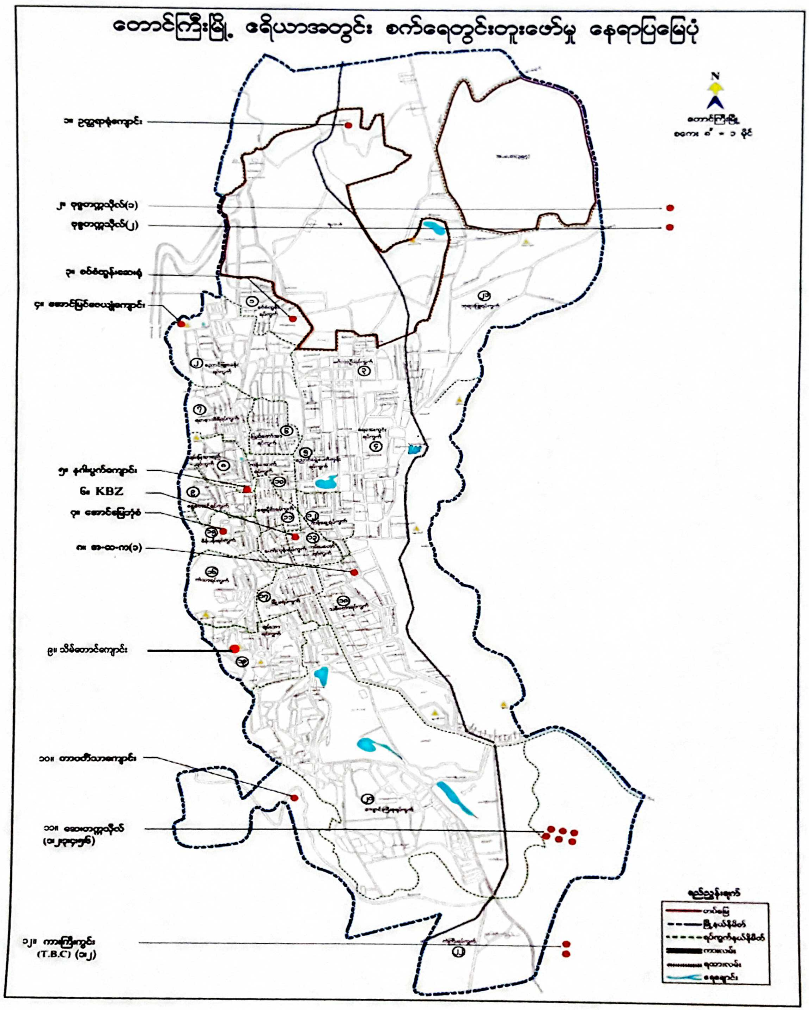


Figure 18: Location of successful WRUD drilled boreholes in Taunggyi town.

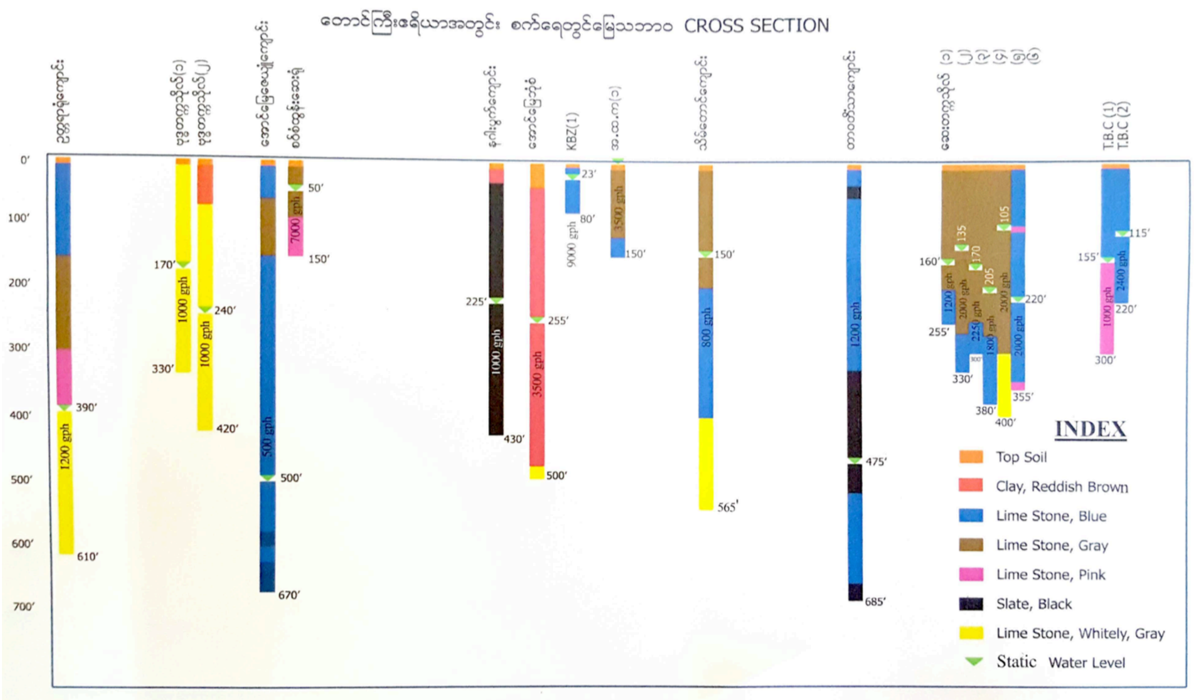


Figure 19: Simplified drilling logs of successful boreholes in Taunggyi town drilled by WRUD.

According to the WRUD data, Taunggyi town is underlain by limestone of various hues with a median static water level of around 200 feet. This is not the depth at which water is found but the level of the water in the well after well completion. It is usually higher than the strike level due to the pressure in the aquifer.

Given the geology reported by the Taunggyi driller, it is likely that either they did not interpret the geology they encountered correctly or they do not drill directly on locations where the limestone outcrops, but instead choose locations that are underlain by alluvium to the west of the town.

Aung Ban contractor

The Aung Ban contractor has 15 years of drilling experience in the area.

He has only been hired directly by a farmer in Heho. He is of the opinion that groundwater for irrigation is only worth exploring around Heho due to the high success rates and flow rates. He reports generally finding only 'soil' in Nyaungshwe and Shwenyaung and limestone in all other areas in question. This information contradicts information provided by the Taunggyi contractor who implied there were good groundwater resources available at Shwenyaung.

Township/Area	Depths (ft)	SWL's (ft)	Flowrates (g/h)	Success Rates
Kalaw / Aung Ban	200 to 600	50 to 200	500 – 2,000	70%
Kalaw / Heho	300 to 550	Artesian to 100	10,000	90-100%
Taunggyi	200	75 to 100	1,000 – 3,000	80%
Nyaungshwe	400 to 500	Artesian to 50	1,000 to 5,000	80%
Pinlaung	400 to 500	150 to 300	500 to 1,000	50%
Pindaya	600 to 700	200 to 350	500 to 1,000	< 50%

Source: Aung Ban drilling contractor based on personal experience, including working with the WRUD.

Shallow Groundwater

Of the villages visited, with the exception of Kalaw, one in each township (total 4 of 12) had access to shallow groundwater, either through self-made shallow dugwells or low cost tubewells. In all cases the water quantity was low and usually sufficient to irrigate between a quarter to one acre, most commonly about half an acre. Shallow groundwater was in each case less than 30ft deep.

Figure 20: Pinlaung township, Inn Gaung village. Low cost shallow (30ft) tubewell with 2" diameter petrol pump irrigates about half an acre.

Figure 21: Pinlaung township, Inn Gaung village. Around 20 farmers have shallow dugwells, between 16 to 20 ft deep, used to irrigate small vegetable plots. A further three or four farmers have shallow tubewells (30ft). Many other farmers attempted to construct additional shallow tubewells but failed due to hitting rock between 15-20ft.

Ground Water Quality

Water quality was not stated as an issue or constraint to irrigation by the WRUD or farmers visited.

However, it is important to note that Karstic aquifers and springs are vulnerable to contamination due to the rapidity that water can sometimes flow through Karstic systems.

Groundwater availability

Due to the scarcity of good quality groundwater data, groundwater resource availability has been generalised based on the anecdotal evidence collected and using general assumptions that can be made based on the geology and topography of the area.

Two aquifer environments can be categorised, an alluvium aquifer located at the base of valleys and a fracture dominated aquifer located within the surrounding ridges of limestones, siltstones and sandstones.

Alluvium deposits

Within alluvium deposited within the valley floors, groundwater is potentially readily available with possible good water resources located closer to the surface that can be accessed relatively affordably using local contractors and smaller rigs.

Both drilling contractors appear to favour drilling locations that are underlain by thick alluvium deposits. In South Shan these occur within the valleys. Both the Inle lake valley and the Heho valley appear to provide potentially good drilling opportunities.

Within the Nyaungshwe and Shwenyaung areas the Aung Ban contractor reported poorer drilling conditions. These towns are situated in the middle of the Inle valley. It is suspected that the contractors simply couldn't drill deep enough. A larger rig drilling in these localities, drilling deeper than 350 feet (106m) might well intersect good aquifers at greater depth close to the rock head. At least one borehole in the Nyaungshwe area provides evidence of good groundwater resources underlying the area.

Figure 22: Nyaungshwe township, Taung Poet Gyi village. An artesian well, roughly 320ft deep, flows year-round into a canal as the construction is unable to contain the pressure if the valves are closed. Following this early 'lucky find' households tried a further 10 deep tubewells, with five failing, four providing a low quantity of water and one having a higher yield, but none were artesian. No other artesian wells were found during the field visits.

Other possible locations where alluvium deposits are present might include Soung Cherry and sites off the route 54 heading south to Pinlaung.

Upland areas

Groundwater movement and storage within the upland ridges composed of limestones, siltstones, sandstones and conglomerates will be dominated by fracturing.

The limestone plateau may exhibit karst features characterised by a network of conduits and caves formed by chemical dissolution.

Karst aquifers are highly heterogeneous and inherently difficult to drill. The water table within upland areas is often deep below land surface. A loss of circulation can occur when non-saturated voids within the rock are encountered. There may be large quantities of water exploitable within a fracture system, but a borehole a few metres away may be completely dry.

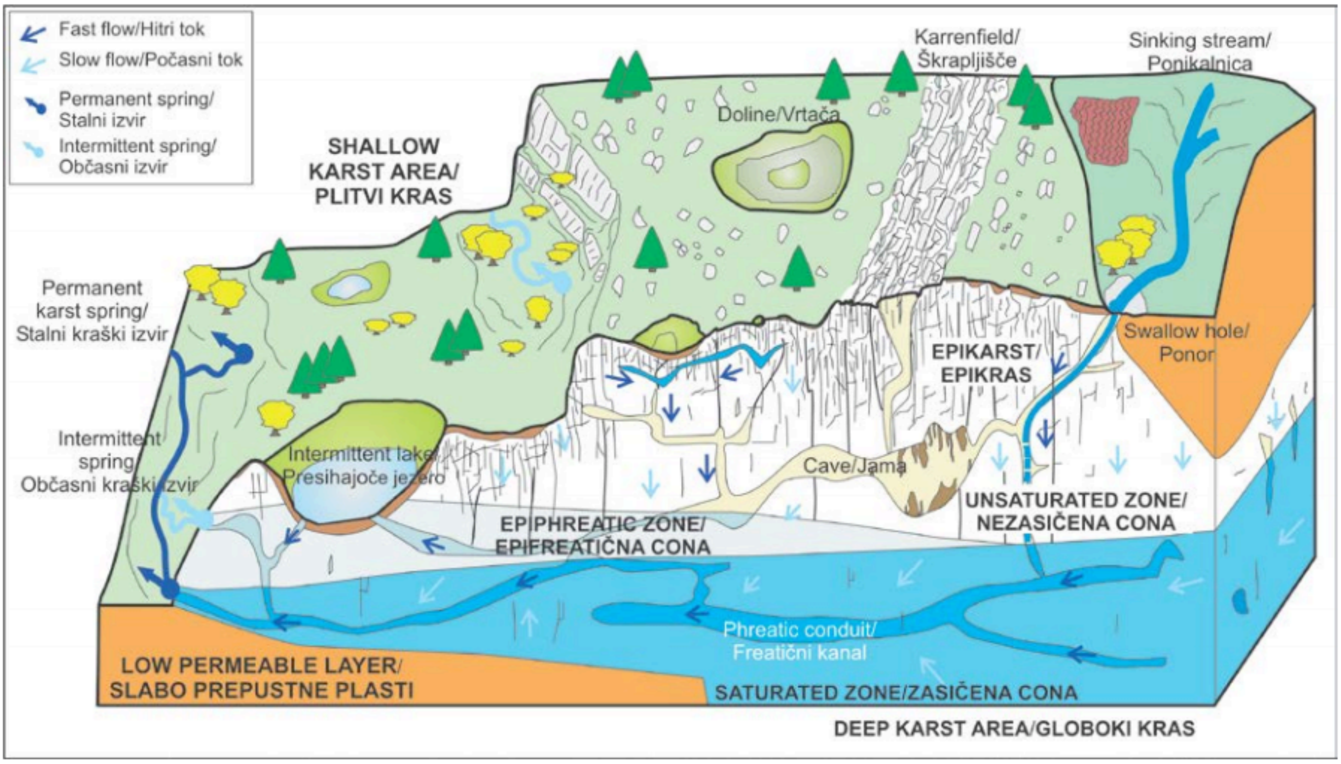


Figure 23: Schematic model of a karst aquifer (Ravbar and Goldscheider, 2007)

Despite these challenges, it is possible to drill successful boreholes. Chances of drilling successful wells can improve through siting boreholes in valleys and at spring heads, where fractures are more likely to occur and groundwater flow is concentrated increasing porosity and permeability of the rock through limestone dissolution. Drilling may also prove more successful at the boundary between different formations. Geophysics can also help with borehole siting.

Groundwater Sustainability

Groundwater sustainability as an irrigation source within the South Shan locality can be calculated through developing a conceptual model of the aquifer system and calculating a water balance where:

Input = Output + Change in Storage

A key input would be groundwater recharge (related to rainfall), while key outputs would include evapotranspiration, spring discharge and groundwater abstraction.

Such a calculation is beyond the scope of this report and would require data including groundwater levels, spring flow and rainfall data.

However, based on the high rainfall the locality receives (1747mm as per data from Taunggyi weather data station (FAO CLIMWAT)) and generally current low utilisation of groundwater, it is likely that the aquifers within the South Shan area are currently under exploited.

Barriers to groundwater development

Capacity of drilling contractors

The two contractors interviewed showed a general lack of hydrogeological understanding and there is a concern that this lack of capacity would be reflected in their drilling practices. Borehole logs were not being accurately created or kept, and geological and hydrogeological information was not being used to aid with borehole siting. Borehole siting was being undertaken through the use of dowsing rods and the different drillers appeared to be providing contradictory information to each other and to the limited data provided by WRUD.

It is considered that with training the drilling contractors could potentially improve their success rates through better siting, improved drilling practices and better data collection. Higher success rates would reduce overall costs associated with drilling and in turn benefit farmers looking to utilise groundwater for irrigation.

Drilling costs and risk

Farmers rarely directly contract borehole contractors as they are unaware of the costs and perceive the risk to be high. However, in some areas contractors are willing to negotiate risk share arrangements, as was witnessed during the field visit.

If a scheme were to be established whereby part of the cost of failed drilling is shared or absorbed, it would reduce the risk for the farmer and help to facilitate growth of the contractor's business. This could be in the form of a type of small scale insurance or subsidy funding.

A major barrier for farmers is a lack of access to cash or credit. There are currently no credit streams available for groundwater prospecting and establishment. In favourable areas with higher drilling success rates and where the pay-back period is estimated at less than 3 seasons (crop cycles), a credit systems could be established to facilitate uptake. As it would be selective it could potentially be managed directly by the contractors rather than through a bank. A microfinance institution would be an alternative.

Agriculture

This chapter explores the main agricultural practises in relation to vegetable farming in the area of interest. We use multiple data sources to analyse the crop water requirement of common vegetables during the off-season. The lack of extension services for irrigation advice is highlighted. We use a range of data sources to analyse the production costs, yields and selling prices of common vegetables, all of which have significant variation. This data is used in the later financial considerations chapter to model the cost benefit of different interventions.

Across South Shan the average household holding size is 3.34 acres with an average parcel size of 1.9 acres (MOAI, 2013a). The number of households with less than an acre decreased by 48% between 2003 and 2010 (MOAI, 2013a).

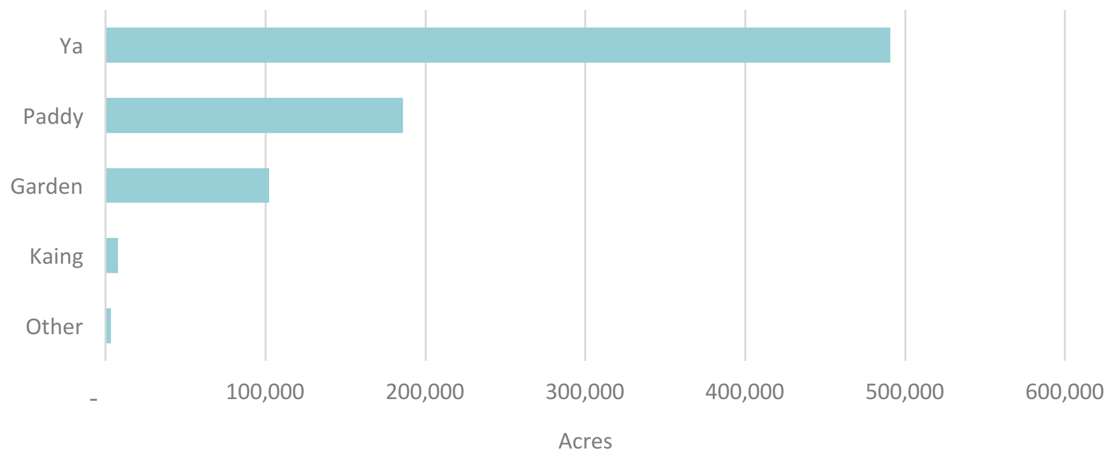


Figure 24: Land types in South Shan in 2010. Ya is dryland, Garden is permanent crops/trees and Kaing is alluvial land, 2010 (MOAI, 2013a)

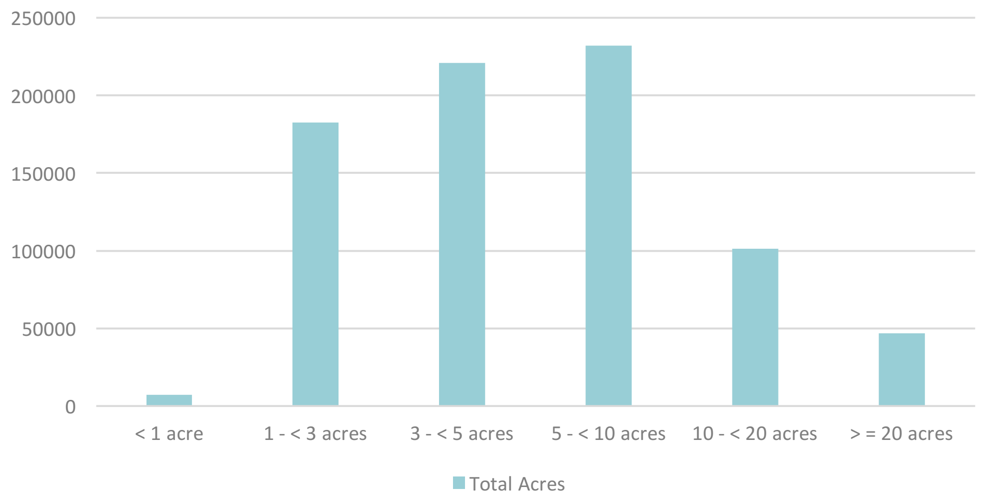


Figure 25: Total area of holding within holding size categories, 2010 (MOAI, 2013a)

The MVMW baseline data shows that at present the most common area of vegetables grown is between half and one acre.

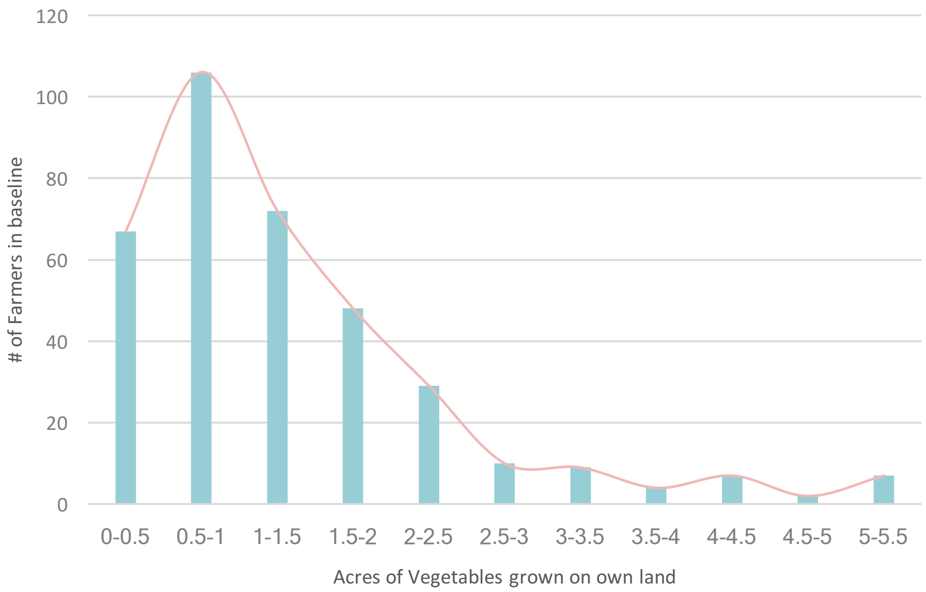


Figure 26: Frequency distribution of acres of vegetables grown on own land by farmers in the MVMW baseline study, as of December 2016.

The last Myanmar agricultural census shows the relative popularity of vegetable crops, with a selection presented below. Data specifically for the off-season is provided for Taunggyi in Table 8.

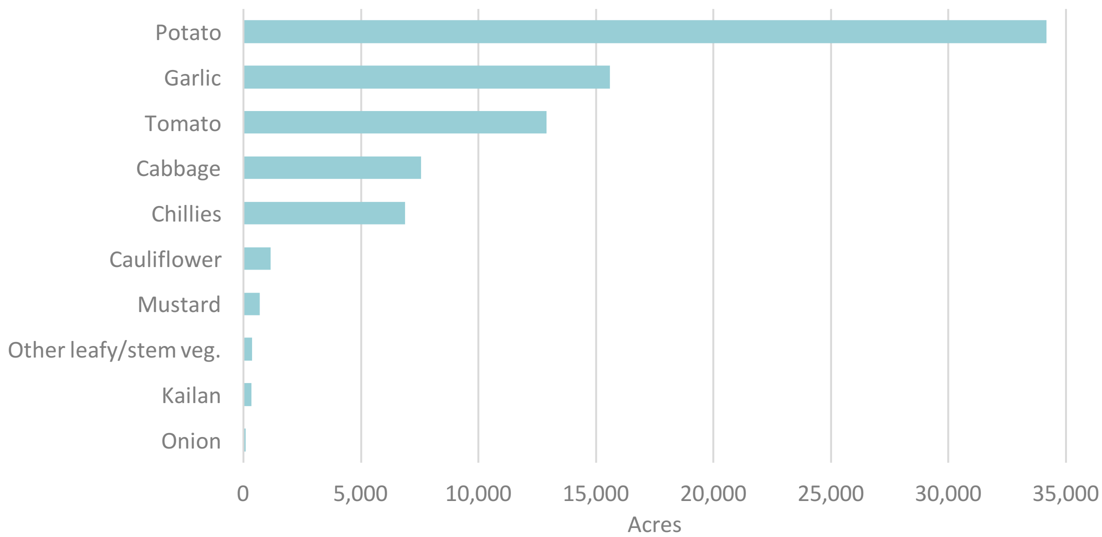


Figure 27: Area planted by popular vegetables and roots over a 12 month period in Taunggyi District, 2010 (MOAI, 2013a)

The soil types are noted below as they form a required input for modelling crop water requirements. The predominant soil types are red and yellow earth. Based on casual field observations it is assumed for the purposes of modelling that the soils are mostly medium loam and clay loam.

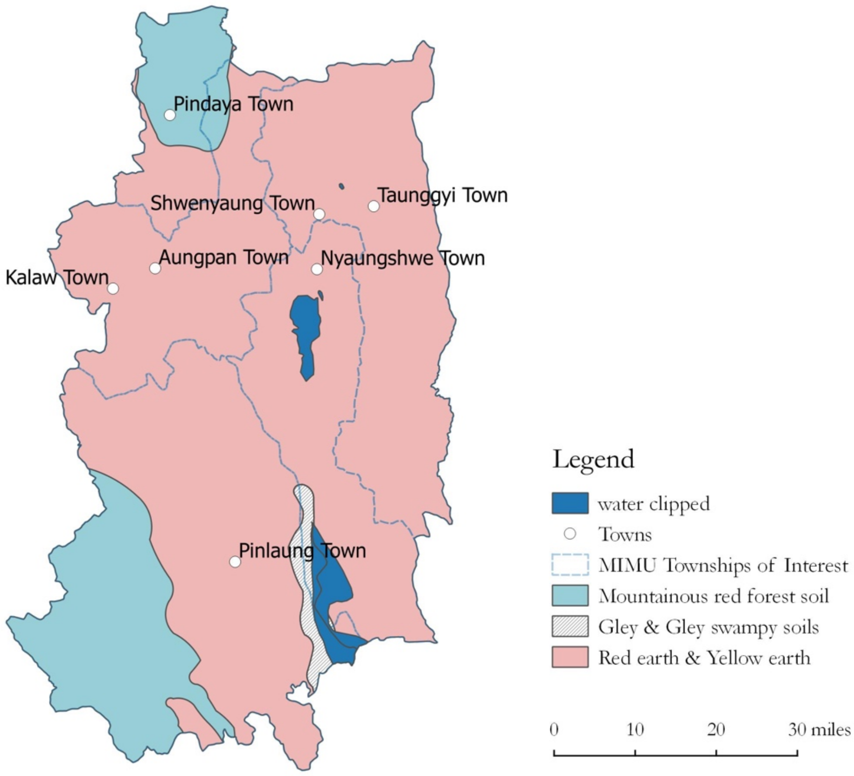


Figure 28: Soil types in the area of interest, traced and reformatted in QGIS from the Myanmar Agricultural Atlas (FAO, 2005)

Cropping calendars

There is significant variation in cropping calendars between farmers in the same village, between villages and between townships making it difficult to produce a representative example. The field team reported that generally a farmer will grow two main crop simultaneously except for in Kalaw township where it is more commonly three. There was significant diversification in crop types. Beyond the vegetables listed in Figure 27, sweet pepper, bitter gourd, cucumber, sweet pea, eggplant and pumpkin were also reported during the field visits. This could suggest increased diversification over the past six years since the last agricultural census data.

Areas which can grow in the off-season using residual moisture depend on heavy clay soil conditions and occurrence of dew. It was reported that residual and dew moisture crops, predominantly wheat, are most common in Taunggyi township and not witnessed by the team in Kalaw.

In Taunggyi vegetable farming in the off-season was reported by the field team and local farmers as being fairly limited. In both Taunggyi and Pindaya corn is the predominant rainy season crop and tomato the most popular off-season vegetable crop. In some areas of Pindaya, with perennial springs or streams, farmers are able to grow three cycles of vegetables during the year.

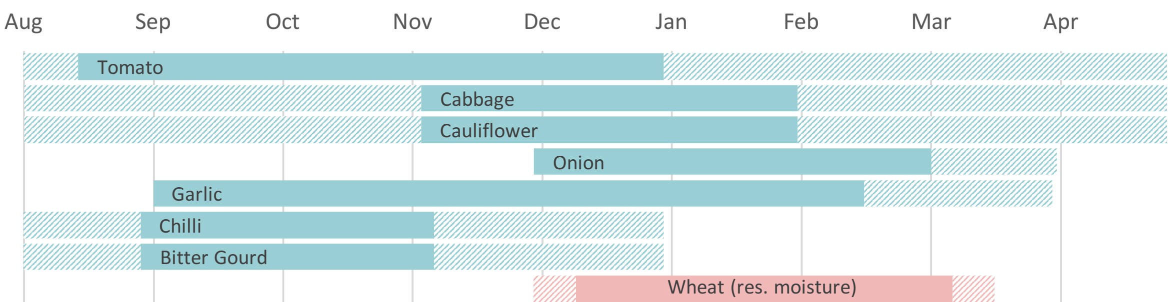


Figure 29: Illustrative cropping calendar showing main off-season vegetable crops, common growing times (solid) and the range of growing times (angled lines)

In Pinlaung the most common crops in the lowlands are rice followed by tomato and cabbage in the off-season and in the uplands garlic and tomato. During the field visit in January the majority of irrigated areas witnessed were growing garlic. In Kalaw township a combination of cabbage, garlic, cauliflower and sweet pepper were reported by the villages visited, with a first cycle from November to February and a second cycle, where water remained sufficient, from February to May.

With many villages around Inle lake, Nyaungshwe township differs from the other areas with many lowland areas flooding in the rainy season. Around the periphery of the lake some perennial growing of vegetables can be found, although non-vegetable crops are reportedly more common. Garlic and rice can be common in the lowlands with flowers further up and very limited off-season cultivation in the uplands.

Crop Water Requirements

Historic climatic data, including reference evapotranspiration (ET_O) calculated with the Penman-Monteith method, was downloaded from a weather station in Taunggyi, extracted from the FAO CLIMWAT 2.0 software and imported into the FAO CropWat 8.0 software (FAO, 2017a). Effective rain is calculated in the software using the dependable rain formula.

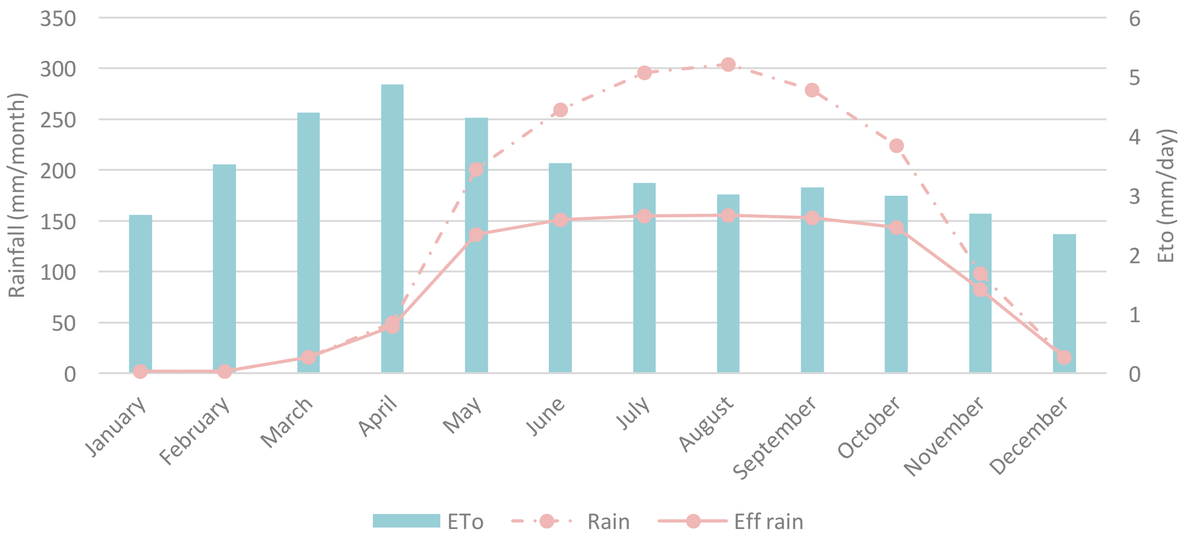


Figure 30: Rain, effective rain and ETo from Taunggyi weather station (FAO, 2017a)

The climate model is on the basis of the average and does not consider risk factors for unusual years. In regards to off-season cropping the expected rainfall in the model is minimal and therefore the impact of no rain during these months minor. The CropWat software can also be run assuming no rainfall during the off-season.

The crop water requirement is calculated by multiplying the reference evapotranspiration (ET_O) from above with the crop coefficient (K_C).

Crop water requirement = Crop coefficient x Reference evapotranspiration (ETc = Kc x ETo)

The crop coefficient values change depending on the growth stage of the crop and therefore the estimated length of growth stages, in days, should also be known. Some Kc values for vegetables, as presented by Rowell and Soe (2016) for their analysis of Myanmar vegetable water requirements, are shown below.

				Late season	
Crop	Scientific name	Initial	Midseason	All vegetables	No water reduction
		----------	---------- K_c	----------	----------
Broccoli	*Brassica oleracea* var. *italica*	0.7	1.05	0.95	0.95
Brussels sprout	*B. oleracea* var. *gemmifera*	0.7	1.05	0.95	0.95
Cabbage	*B. oleracea* var. *capitata*	0.7	1.05	0.95	0.95
Carrot	*Daucus carota*	0.7	1.05	0.95	0.95
Cauliflower	*B. oleracea* var. *botrytis*	0.7	1.05	0.95	0.95
Celery	*Apium graveolens*	0.7	1.05	1	1
Garlic	*Allium sativum*	0.7	1	0.7	
Lettuce	*Lactuca sativa*	0.7	1	0.95	0.95
Onion (dry)	*Allium cepa*	0.7	1.05	0.75	
Onion (green)	*A. cepa*	0.7	1	1	1
Spinach	*Spinacia oleracea*	0.7	1	0.95	0.95
Radish	*Raphanus sativus*	0.7	0.9	0.85	
Eggplant	*Solanum melongena*	0.6	1.05	0.9	
Bell pepper	*Capsicum annuum*	0.6	1.05	0.9	0.9
Tomato	*Solanum lycopersicum*	0.6	1.15	0.8	
Muskmelon	*Cucumis melo*	0.5	0.85	0.6	
Cucumber	*Cucumis sativus*	0.6	1	0.75	
Pumpkin, winter squash	*Cucurbita pepo*, *Cucurbita maxima*	0.5	1	0.8	
Zucchini squash	*C. pepo*	0.5	0.95	0.75	
Sweet melon	*C. melo*	0.5	1.05	0.75	
Watermelon	*Citrullus lanatus*	0.4	1	0.75	
Table beet	*Beta vulgaris*	0.5	1.05	0.95	0.95
Potato	*Solanum tuberosum*	0.5	1.15	0.75	
Sweetpotato	*Ipomoea batatas*	0.5	1.15	0.65	
Green bean	*Phaseolus vulgaris*	0.5	1.05	0.9	0.9
Mean		0.61	1.03	0.85	0.95
SD		0.1	0.07	0.12	0.03
CV (%)		16.4	6.6	13.7	3.2

Table 4: Kc values. From (Rowell and Soe, 2016)

When inputting data into CropWat a range of other factors are needed including the rooting depth, critical depletion, yield response factor and crop height. The FAO has a selection of preloaded crops which can be loaded into the software.

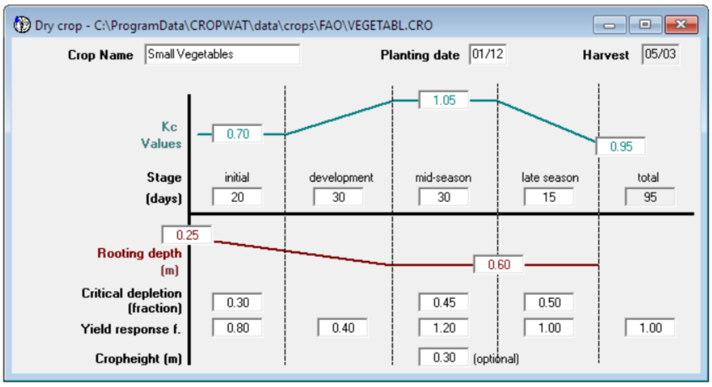


Figure 31: Screenshot of crop data required to produce CropWat models and the FAO preloaded example for 'small vegetables'.

The CropWat model was applied, using Taunggyi Climwat data and the available FAO standard crop profiles to produce the illustration below. A standard FAO profile for garlic was not available so FAO K_c values, crop height and critical depletion values were used. No data could be found for garlic stage lengths or yield response so these were estimated.

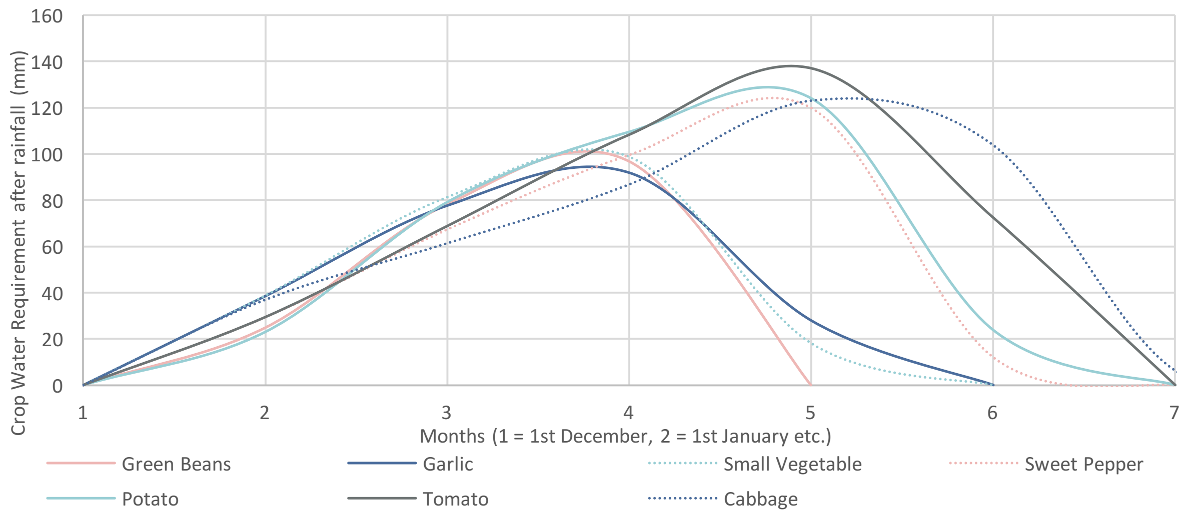


Figure 32: Crop irrigation requirement for selected vegetables based on a planting date of 1st December in Taunggyi. This model takes into account the expected rainfall.

The above crop irrigation requirements were converted to the required volume of water per acre for the total crop period. This then represents the requirement of the crop only. In order to take into account the losses of the water application method it must consider the efficiency.

> Volume of Water per Acre (m^3/acre) = Crop irrigation requirement (mm) / 1000 x 1 (acre) x 4047 (m^2/acre)
>
> Applied Volume of Water per Acre (m^3/acre) = Volume per Acre (m^3/acre) / Efficiency of method (% / 100)

There are differing figures presented in literature for the efficiency of different irrigation methods, particularly furrow. Irrigation efficiency options are discussed later in this report. In order to provide a rough guide a 80% efficiency was assumed for sprinklers and 60% for furrow.

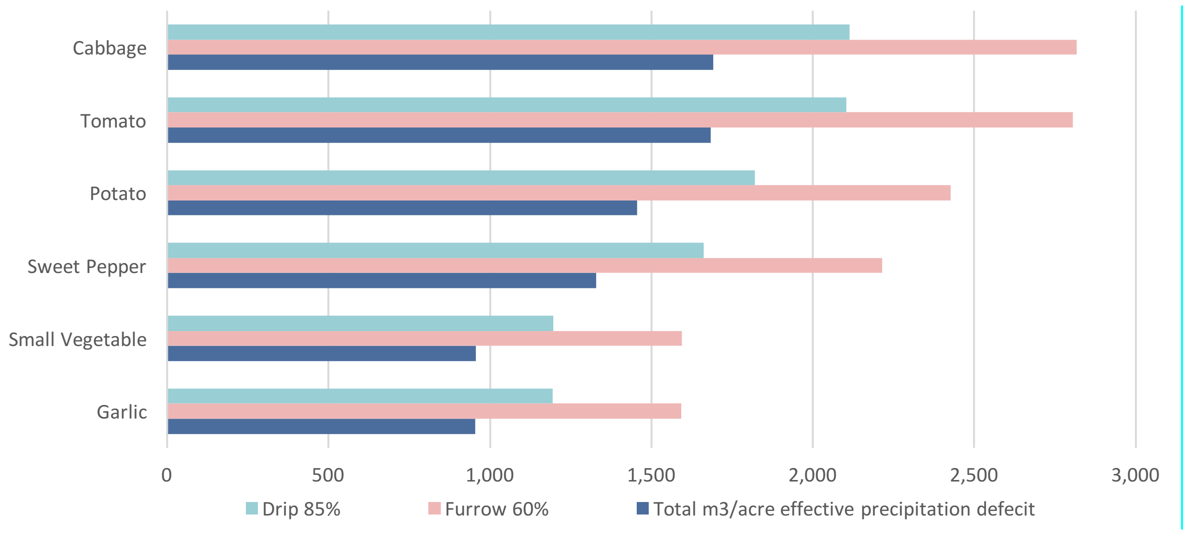


Figure 33: Crop water requirements (after rainfall) in m3 per acre for different types of irrigation based on a 1st December planting date.

When drip irrigation is used these figures need further adjustment as a drip system would typically only be irrigating half the land and therefore the volume required per acre would be less.

These calculations are interesting on the basis of estimating current water usage and potential water saving. It is unknown how closely farmers actual practise correlates to these theoretical requirements. This study did not look into how farmers determine irrigation schedules or what quantity of water to apply. Although a fundamental part of agriculture, such advice is not offered by government or private sector extension workers.

The Myanmar organisation Proximity Design acknowledged the farmer knowledge gap while promoting low cost drip systems and developed a water wheel for drip irrigated vegetable crops, shown below. The article explaining its use reported that out of the 456 farmer in their study, 74% used the advice from the wheel and 87% of the 54 extension workers reported that the wheel was 'very helpful and useful' for their work (Rowell and Soe, 2016). It is unknown if the wheel is still in use.

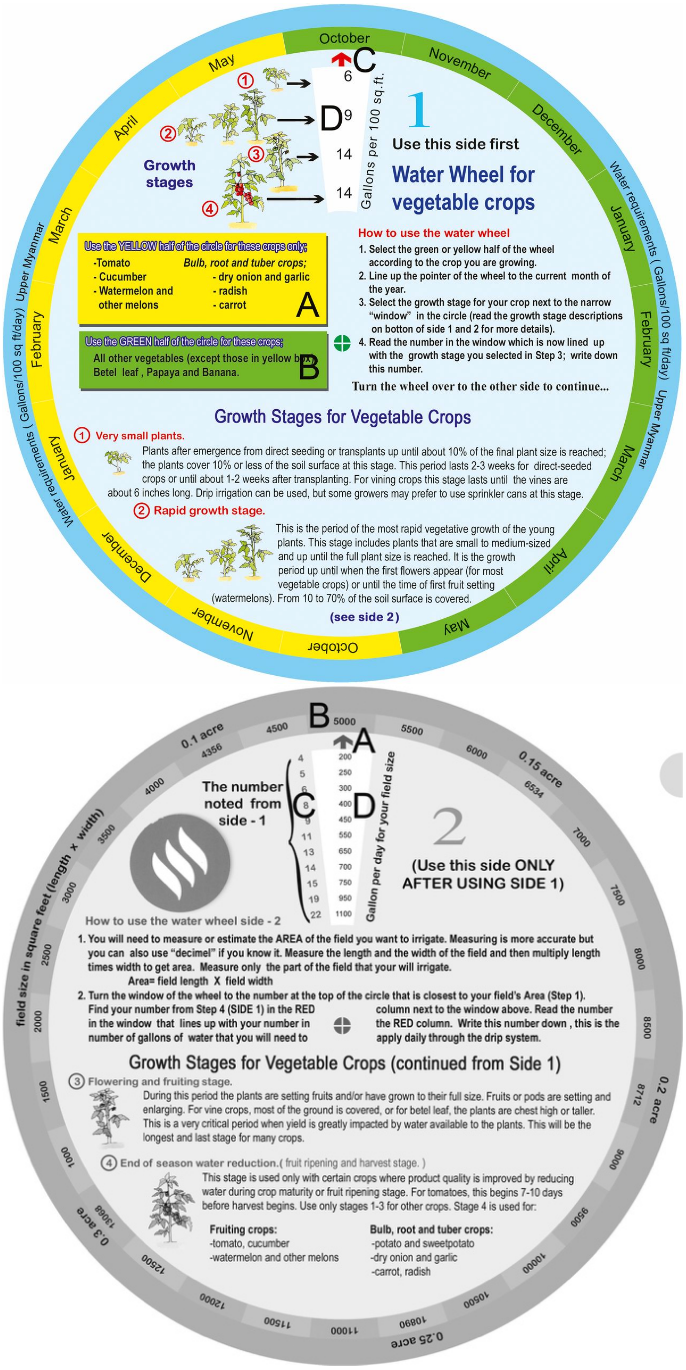


Figure 34: "Water Wheel for vegetable crops for Upper Myanmar. The wheel consists of an inner stationary disc and outer rotating disc used to determine water requirements per 100 ft2 (9.29 m2) based on average evapotranspiration (ET), growth stage, and crop coefficients. Colored boxes on the left side indicate crops with (A) and without (B) water reductions at harvest. The red arrow (C) is lined up with the appropriate month of the dry season to read the water requirement in gallons (D); 1 gal/100 ft2 = 0.4075 L mL2". (Rowell and Soe, 2016).

Water Productivity

It is not recommended that water productivity is used as a primary driver or measure for any programs supporting increased irrigation coverage or efficiency. However, due to its widespread use the concept is briefly discussed.

The concept of crop water productivity, as measured by the kg of crop produced per m3 of water, has become a popular and widely used concept in irrigation literature, often termed the 'crop per drop'. However, it is recognised by the World Bank and others that in reality this is usually an unhelpful oversimplification (Scheierling et al., 2014)(Wichelns, 2014)(GWF, 2014) . As a single-factor productivity ratio it is easy to calculate but fails to consider the bigger picture relationship with other inputs and factors (Scheierling et al., 2014). For example, achieving the highest 'crop per drop' ratio could theoretically be achieved with minimal water input and a reduced yield.

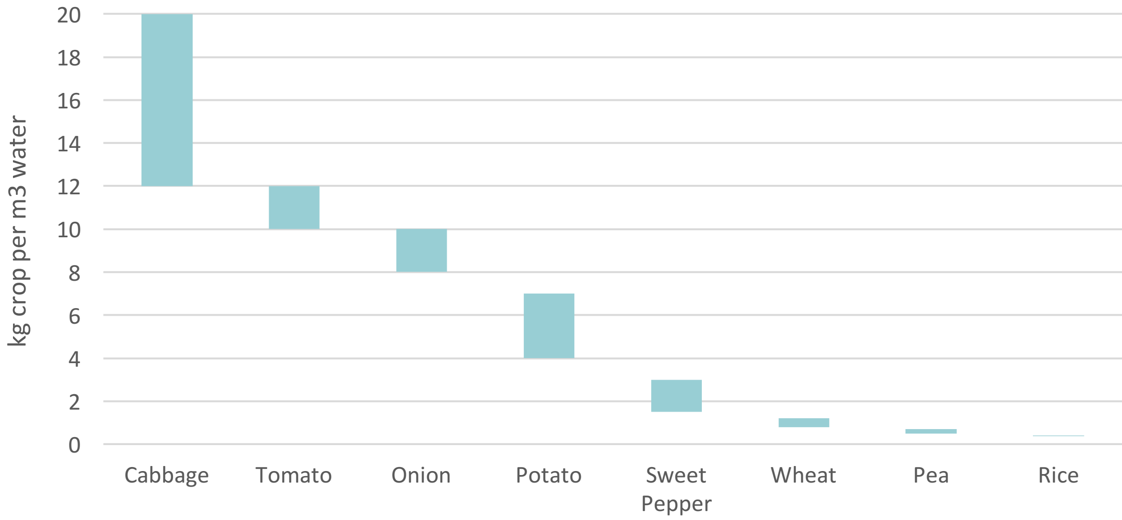
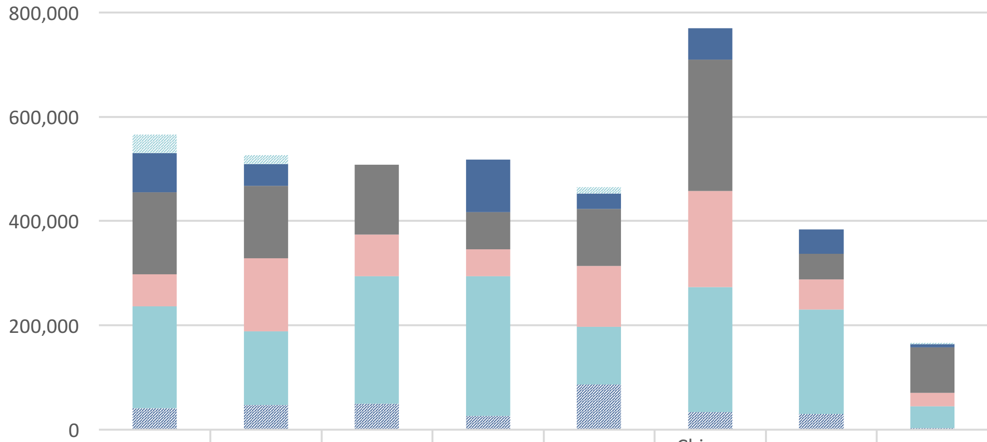


Figure 35: Water productivity of selected vegetable crops with wheat and rice for comparison. Rice data (Cai and Rosegrant, 2003), all other data from FAO Water (FAO, 2017b)

Crop Production costs



	Tomatoes (dry)	Tomatoes (rain)	Cabbage (dry)	Cabbage (rain)	Snow pea (dry)	Chinese Cabbage (rain)	Cauliflower (rain)	Hot pepper (rain)
Average of Packing/Acre	36722	17863			12500			2354
Average of Transportation/Acre	74905	41576		101000	29741	60000	47333	5778
Average of Labor/Acre	157460	139234	134313	71537	109333	252500	48333	87500
Average of Pesticide/Acre	61441	139988	79583	50893	117027	184400	57708	25000
Average of Fertilizer/acre	194898	141431	245042	268761	110167	239333	201250	42979
Average of Seed / acre	40952	46886	48875	25826	86444	33800	29178	1896
Total	566,378	526,978	507,813	518,017	465,212	770,033	383,803	165,507

Figure 36: Production costs for selected vegetable crops for plots >=0.5 acre (MVMW, 2016a)

Data was extracted from the MVMW baseline report (as of December 2016) to determine the average cost of inputs for selected vegetable crops in the rainy and off season. Although the MVMW baseline groups seasonal costs and does not explicitly collect individual crop based input cost data, only 34 of 364 famers in the rainy season reported growing more than one crop and 10 of 222 in the off-season. Therefore, in most cases the seasonal cost data was in fact crop specific.

For all input cost categories the data was converted into a cost per acre based on the farmers self-reported plot size. The initial data had significant variation in the per acre costs between farmers. It is suggested that this was due to inaccurate reporting of the true size of small plots leading to magnified errors when scaled up to per acre costs. As a result, the data was cleaned to include only plot sizes >= 0.5 acres and any clearly major outliers removed. The graph and table below show the resulting average input costs for selected vegetable crops.

As the baseline data did not include data for Onion of Garlic on plots >=0.5 acres information from MOAI (2012/13) was used. An annual inflation rate of 7% for 5 years was applied to provide an estimate of the current cost.

	Production cost per acre (2012/13)				Production cost per acre (2017 estimate)			
	Family Labour	Hired Labour	Material Cost	Total	Family Labour	Hired Labour	Material Cost	Total
Onion	16,500	223,500	283,000	**523,000**	23,142	313,470	396,922	**734,000**
Garlic	52,000	175,000	378,000	**605,000**	72,933	245,447	530,165	**849,000**

Table 5: Production costs for onion and garlic as of 2012/13 scaled up based on 7% inflation (MOAI, 2013b)

Combining both sets of data and rounding up to the nearest 10,000 for simplification provides the following total production costs per acre in the off-season. The cost of pumping water in the off-season is not included in the data. Production costs for other vegetables of interest were not available or the data set was too small to use.

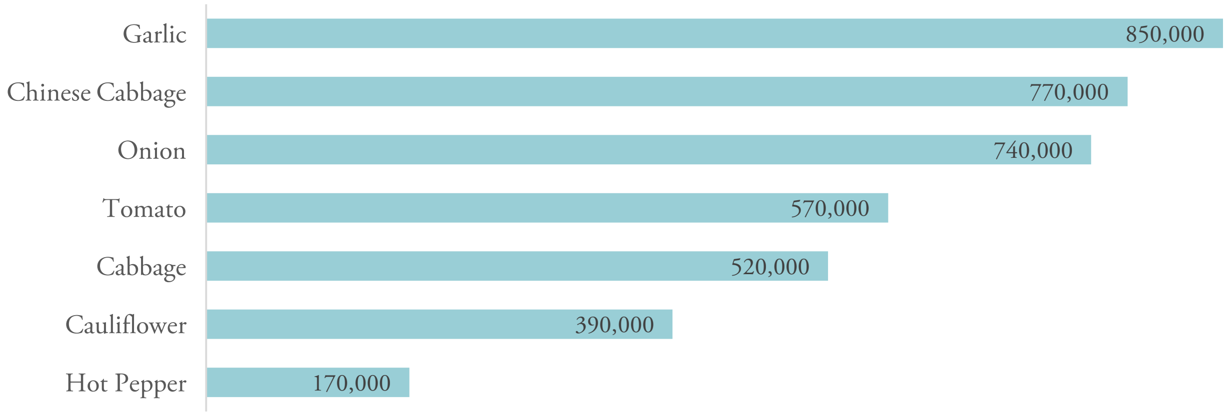


Figure 37: Final production costs of selected vegetable crops used for this model

Yields

Data from the 2004 agriculture sector review shows that in general South Shan has the highest vegetable yields of any area in Myanmar, often by a significant margin (FAO, 2004a). The graph below shows the significant variation in yield per acre from the MVMW baseline data prior to data cleaning. This data is for the rainy season as there were insufficient off-season data points due to most farmers growing potatoes, which are not a crop of interest for the program. The baseline measure of unit per acre refers to the local unit measure of the crop. For example, tomato is measured in viss and cabbage and cauliflower by piece. For tomatoes the average of 3,047 viss/acre and maximum of 15,000 viss/acre translates to 4,997 kg/acre and 24,600 kg/acre respectively, for example.

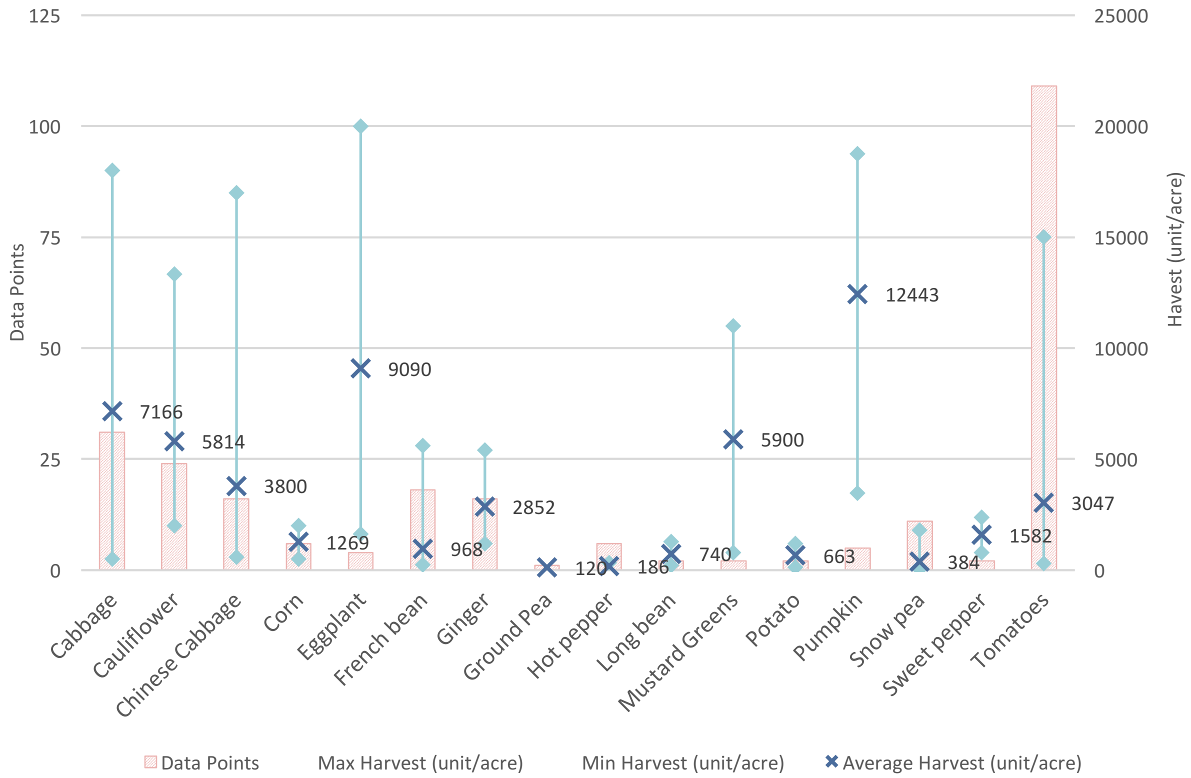


Figure 38: Yields in local unit of measure per acre in the rainy season (MVMW, 2016a)

Due to the significant variation in yields as reported through the baseline, other sources were sought as follows and summarized in Table 6:

i. EWS TP: East West Seed Traditional Practises, as measured in South Shan (Morris, 2017).
ii. EWS IP: East West Seed Improved Practised, as measured in South Shan and after East West Seed interventions (Morris, 2017).

iii. ASR SS: FAO Agriculture Sector Review, tables in working paper 10. Specific yields for South Shan. (FAO, 2004a)
iv. MVMW: Mercy Corps MVMW program baseline data average. Data for planted plots less than 0.5 acres is excluded to improve data accuracy. Cabbage and cauliflower was reported in pieces per acre and converted to viss based on an average of 1.5 viss per piece. 1 viss is equal to 1.64KG. Crops with less than 4 data points are excluded. Potato is excluded as it is not part of the MVMW program. The data is from the rainy season due to insufficient data points in the off-season.
v. Taunggyi DoA: Data provided by Taunggyi township DoA, South Shan State, for off-season yields in the 2015/16 season.
vi. Pinlaung: Garlic yields as reported by farmers in 2 villages visited in Pinlaung township during the field work for this study.
vii. MOAI: National average yields for the year 2012/13 (MOAI, 2013b).
viii. Model: Is the figure selected by the author based on the available data to be used for the cost benefit or payback period models that follow. It is intended to represent current general 'unimproved' practises and therefore be a baseline figure.

(Kg/acre)	EWS TP	EWS IP	ASR SS	MVMW	DoA Taunggyi	Pinlaung	MOAI	*Model*
Tomato	11,336	16,194	9,100	5,046			4,566	*5,000 - 10,000*[2]
Garlic					3,928	3,200		*3,200*
Cabbage			9,878	17,928			6,182	*15,000*
Chinese Cabbage				6,653				*6,600*
Lettuce			6,154				2,615	*6,000*
Cauliflower			8,704	15,173			5,627	*15,000*
Sweet Pepper				2,594				*2,600*
Hot pepper	8,097	10,526						*8,000*
Bitter Gourd	2,429	4,049	1,862				4,579	*2,500*
Ridge Gourd	1,295	1,943	1,862					*1,300*
Yard Long Bean	8,097	9,717						*8,000*
Cucumber	6,073	7,287						*6,000*
Sweet Corn	2,024	2,631						*2,000*
Okra	5,870	7,692						*6,000*
Radish	10,121	12,145					4,700	*10,000*
Onion					2,952			*3,000*
Mustard Greens							3,081	*3,000*
Eggplant				14,908				*15,000*
French Bean				1,071				*1,000*

Table 6: Yield of vegetable crops

As can be seen, there is notable variation between credible data sources. For example, tomato yields vary significantly between MVMW baseline data (5,046), the also credible South Shan specific agriculture sector review (9,100) and the also credible East West Seed baseline data for traditional practises (11,336). This could be due to significant heterogeneity across South Shan.

Field losses are taken into account in the reported yields.

Crop Selling prices

Market price data from Aung Ban, collected frequently since April 2015 by Mercy Corps, highlights the significant fluctuation in farmer selling prices. Large variation in prices can be seen between 2015 and 2016 within the same months. For example, tomatoes were priced around 500 MMK/kg in June 2015 and between 140% and 220% higher at between 1,200 and 1,600 MMK/kg in June 2016. Conversely, tomatoes were priced

[2] As tomato is a key crop and there is large variation between two credible sources (MVMW and EWS TP) two figures are used rather than an average.

around 700 MMK/kg in October 2015 and between 71% lower at 200 MMK/kg for a brief time in October 2016.

These large percentage variations, which have a critical impact on farm profitability or loss, demonstrate the challenges in producing cost benefit or payback period analysis.

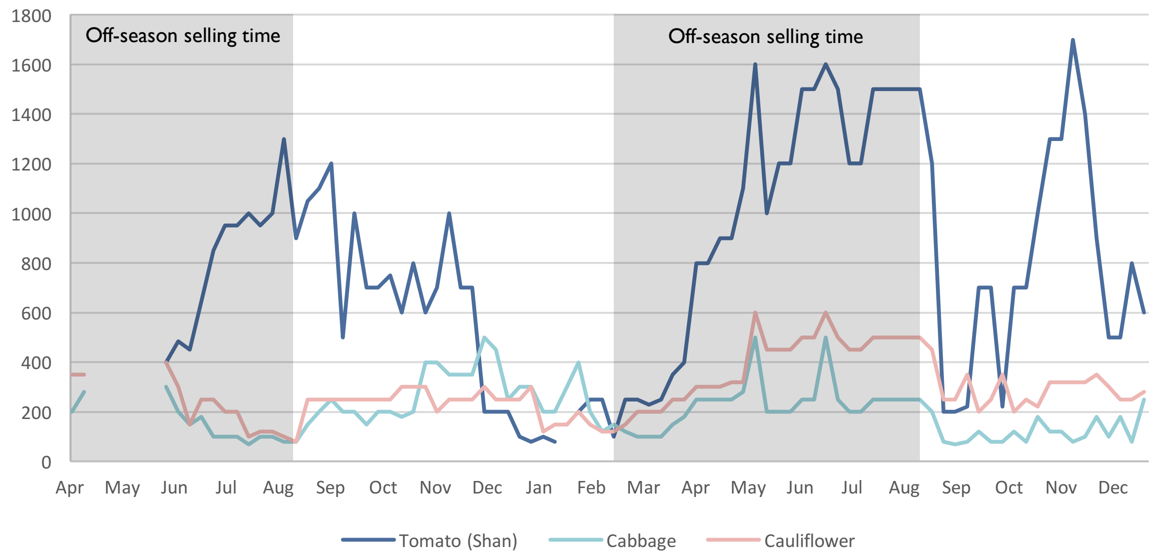


Figure 39: Aung ban market price per viss (tomato) and per piece (cabbage, cauliflower) to the farmer from April 2015 to December 2016 for tomato, cabbage and cauliflower (MVMW, 2016b)

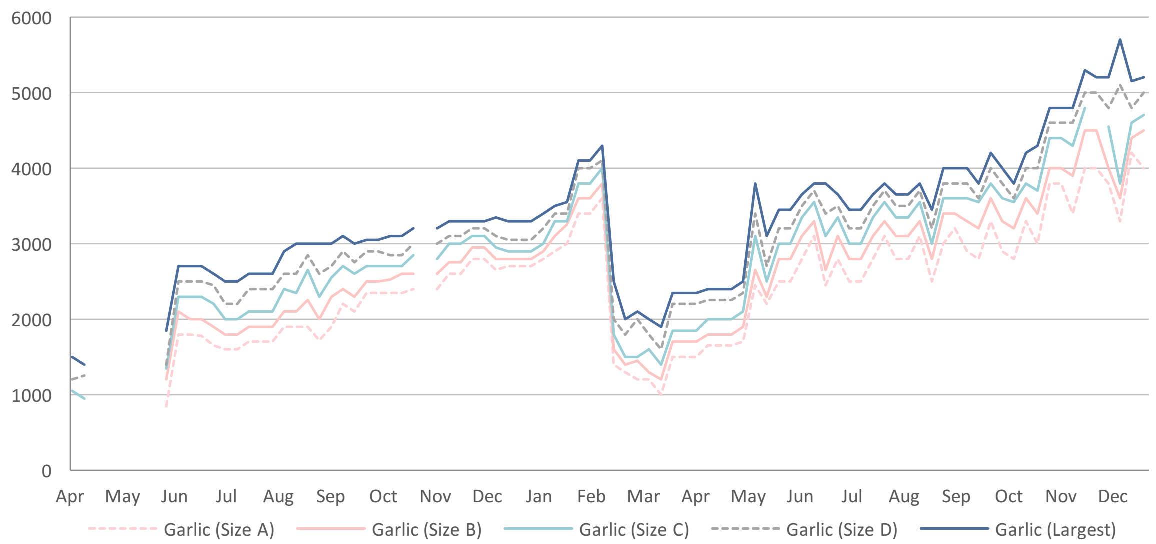


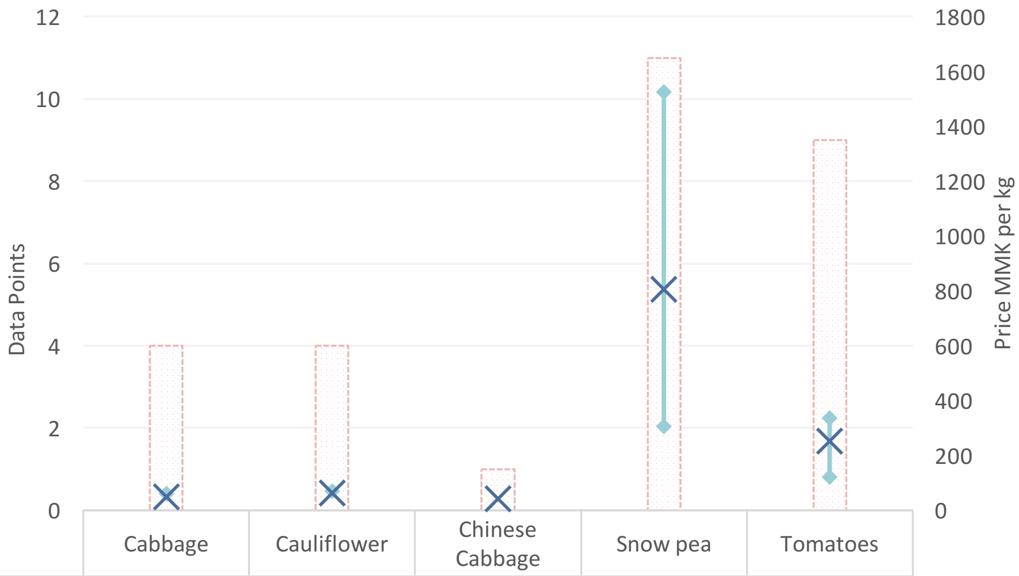
Figure 40: Aung ban market price per viss to the farmer from April 2015 to December 2016 for garlic (MVMW, 2016b)

The market price tracking data is currently too short to create a statistical forecasting model. The graph below shows the maximum, minimum and average selling prices as reported through the MVMW baseline survey. As most respondents were growing only potato in the off-season the number of data points for vegetables of interest is low.

Both the baseline and market price tracking data collect prices per local unit of measure, which is crop specific (viss, piece, basket etc.). To convert to a price per kg the following conversions were used:

1 viss = 1.64 kg

1 piece cabbage of cauliflower = 1.5 viss = 2.46 kg



	Cabbage	Cauliflower	Chinese Cabbage	Snow pea	Tomatoes
Data points	4	4	1	11	9
Max selling price	61	69	42	1,524	335
Min selling price	37	51	42	305	122
Average selling price	49	62	42	805	251

Figure 41: Off-season selling price variation in MMK per kg for selected vegetables (MVMW, 2016a)

Price data from the MVMW baseline and market price survey have some variation. In general, it appears that the farmers interviewed for the baseline were not able to achieve average market price during the February to August period. Ignoring Chinese cabbage due to only a single data point, baseline farmers were achieving an average price around half that which would be expected based on the average market price data.

As market price fluctuation is the most significant variable for a farmer, the cost analysis model uses low, average and high scenarios instead of a single point average. For the cost benefit and payback period models the lowest minimum and largest maximum prices from either data source are taken. The averages are taken from the market price data due to the small sample sizes in the baseline data.

MMK / kg	MVMW Baseline Data for off-season (sample size in brackets)	MVMW Market Price Data for February to August	**Model (min. / average / max.)**
Tomato (Shan)	122 / 251 / 335 (9)	152[3] / 550 / 976	**122 / 550 / 976**
Cabbage	37 / 49 / 61 (4)	28 / 81 / 203	**28 / 81 / 203**
Cauliflower	51 / 62 / 69 (4)	33 / 129 / 244	**33 / 129 / 244**
Chinese Cabbage	42 / 42 / 42 (1)	61 / 596 / 915	**42 / 596 / 915** [4]
Garlic (size C)	*no data*	579 / 1481 / 2439	**579 / 1481 / 2439**
Hot pepper (short)	*no data*	305 / 428 / 793[5]	**305 / 428 / 793**
Sweet Pepper	*no data*	274 / 581 / 1524	**274 / 581 / 1524**

Table 7: Selling prices in MMK per kg for selected vegetables. Prices show minimum / average / maximum.

[3] Ignores a <7 day period where the price dropped to 100

[4] Uses market price data as baseline sample size is only 1.

[5] Average and maximum figures exclude data from a severe price spike in early 2015 (1,700 to 3,658 MMK/kg)

Irrigation Extent

This chapter looks at the current extent of irrigation as per the latest agricultural census, department of irrigation figures and recent data from Taunggyi township where it was reported that around half of the off-season cropped areas are grown with residual moisture. We then summarise the findings of a GIS remote sensing analysis which estimates that almost 68,000 acres are cropped in the off-season. Detailed GIS files are available with Mercy Corps and an overview map presented here which shows the off-season cropped areas and the location of streams; a further map which was produced for this report.

As per the 2010 agricultural census 24% of crop holdings in South Shan are irrigated, representing 192,017 out of a total of 790,388 acres. It is unknown if this double counts land where two crop cycles are grown under irrigation.

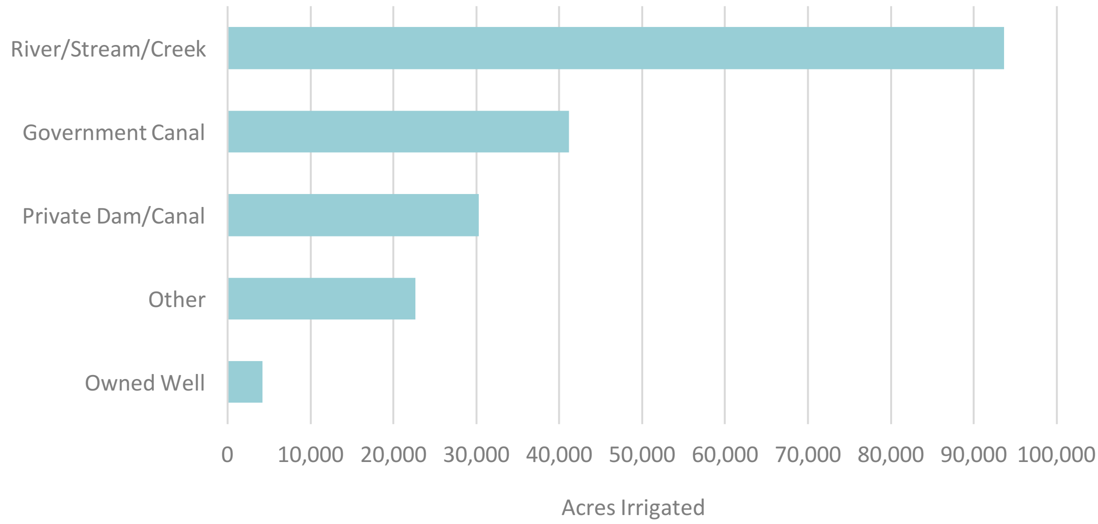


Figure 42: Area irrigated in South Shan by irrigation water source type (MOAI, 2013a)

As shown below, the census reports that the majority of irrigated parcels are between 1 and 3 acres, with a relatively small proportion being less than an acre. The plots seen during the field visit were most commonly between 0.5 to 1.5 acres based on observations.

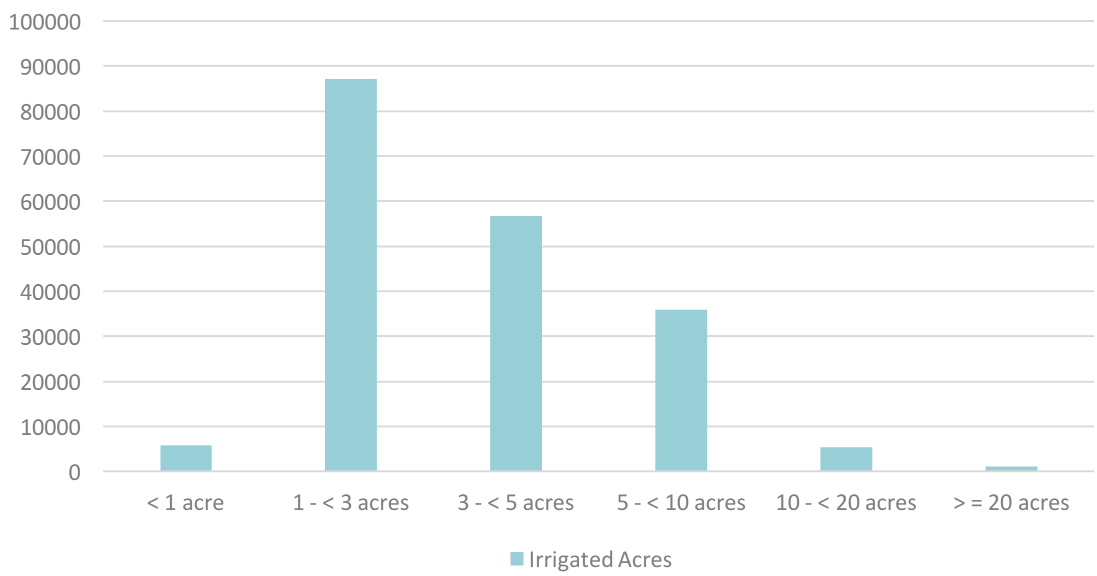


Figure 43: Acres irrigated by the size of the irrigated parcel in South Shan (MOAI, 2013a)

Figure 44 below shows the extent of cropped and irrigated areas for all of South Shan based on data in the 2010 agricultural census. The proportion of irrigated land appears greater than would be expected by the field teams based on their experience.

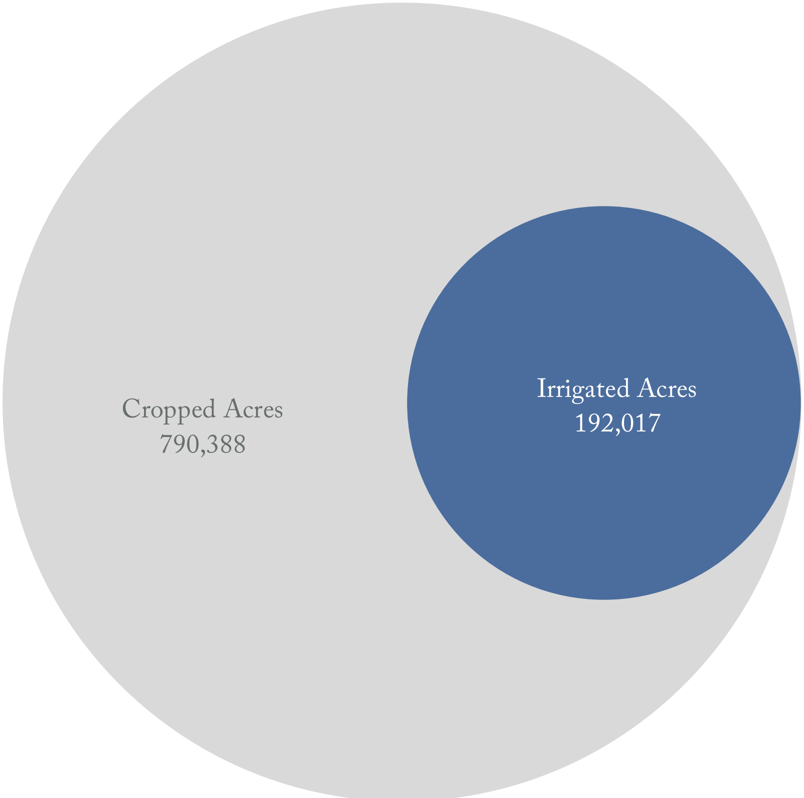


Figure 44: South Shan cropped and irrigated acres from 2010 census (MOAI, 2013a).

The irrigated area is greatest between November and January when water is most plentiful. A smaller area can be irrigated for a second off-season crop sometime between January and May as irrigation water increasingly reduces towards the end of the dry-season. With most irrigation water coming from streams, river and canals the majority of irrigation forms a boundary along these waterways.

Figure 45: Google earth image within Pinlaung township showing clearly the irrigated extent in January 2012 as a boundary to the stream in blue.

Data provided by Taunggyi township DoA provides details of all crops grown in the last (2015-16) off-season and their yields. It is understood that similar data could be obtained from the other township DoA's. This would be worthwhile in order to form a complete baseline of crop choices, DoA claimed irrigation extent and yields.

Taunggyi	Harvested Acre	Harvest Rate (Yield) (Unit/Acre)	Harvested Amount (Total Yield)	Irrigated (acres)	Residual Moisture (acres)
Wheat	2,704	31.51	85,203	-	2,704
Ground Nuts	25	51.64	1,291	25	-
Sunflower	572	31.87	18,230	572	-
Mustard Seed	64	9.17	587	-	64
Niger	5,967	8.48	42,120	-	5,967
Mustard (Oil seed)	447	7.73	3,455	-	447
Other varieties of peas/beans	1,397	8.72	12,178	1,397	-
Soy bean	15	17.20	258	15	-
Chick peas	139	11.44	1,590	-	139
Lentil	175	10.85	1,899	175	-
LabLab Bean	130	9.80	1,274	130	-
Other Pulses	938	7.63	7,157	938	-
Onion	122	1800	219,688	122	-
Garlic	2,649	2395.00	6,344,355	2,649	-
Potato	225	4191.60	943,110	225	-
Other Vegetables	2,191	4947.64	10,840,281	2,191	-
Total				***8,439***	***9,321***

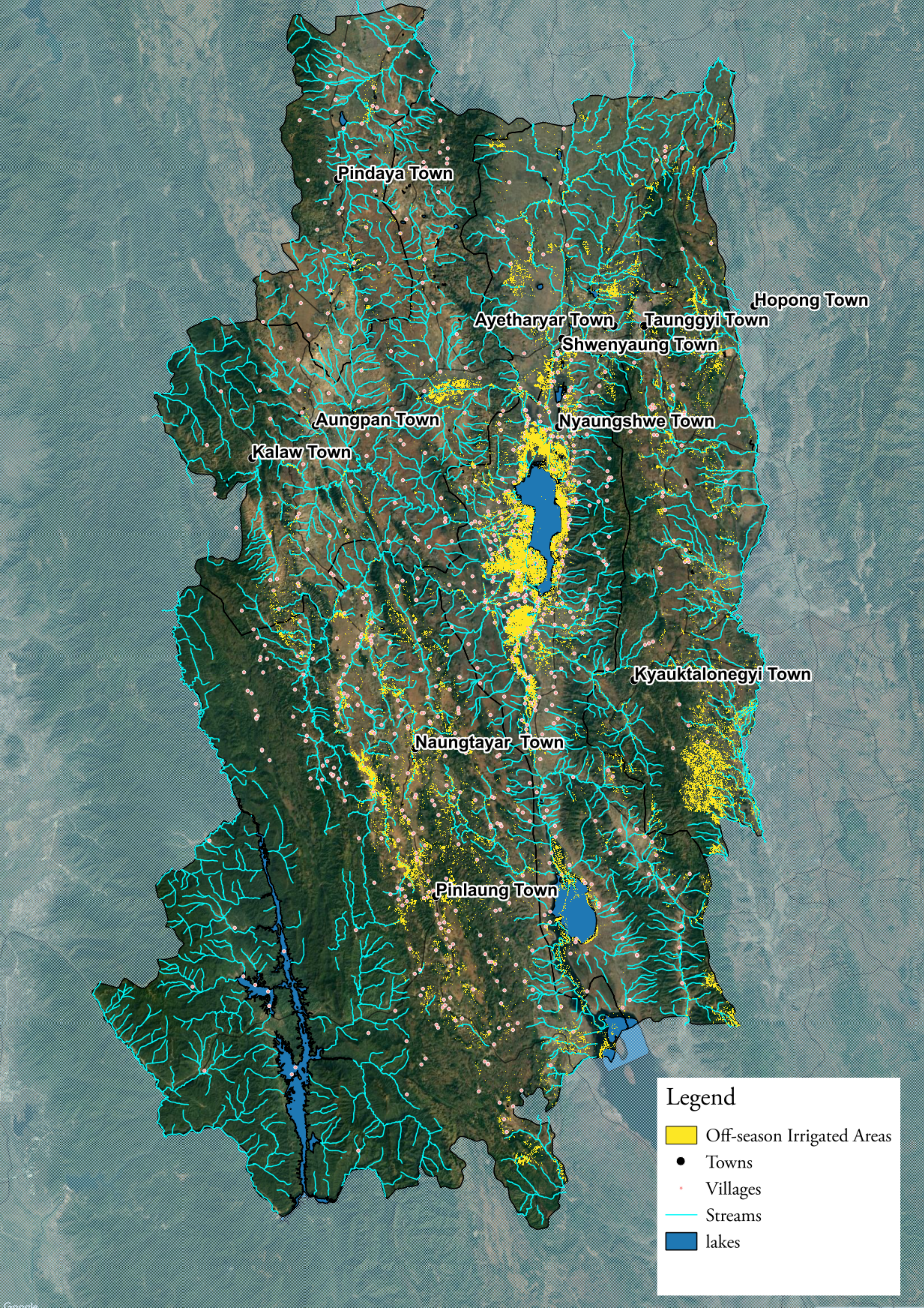
Table 8: Harvested acres, yield rate and total yield for Taunggyi township winter (off-season) crops in 2015-16. Source: DoA Taunggyi township

Formal Irrigation

Information provided by the State DoI shows that across the area of interest a total of 45,000 acres can be irrigated from water created by dams. Across all of Taunggyi district the figure is almost 100,000 acres. The DoI stated that at present they have no plans to construct new dams and are instead focusing on improving or upgrading existing village constructed and managed dams. They suggested that on average the small dams which they construct cost around $150,000 each.

Township	DoI Managed		Village Managed		Development Projects		Private Construction		Total	
	No. Dams	Acres irrigated	No. Dams	Acres irrigated	No. Dams	Acres irrigated	No. Dams	Acres irrigated	No. Dams	Acres irrigated
Taunggyi	6	10,337	8	4,610	2	590	8	3,098	***24***	*18,635*
Nyaungshwe	2	6,527	12	5,550	-	-	1	450	***15***	*12,527*
Pindaya	-	-	1	1,000	-	-	7	5,385	***8***	*6,385*
Kalaw	1	4,599	5	1,128	1	45	-	-	***7***	*5,772*
Pinlaung	-	-	2	624	5	19	2	983	***9***	*1,626*
Totals	*9*	*21,463*	*28*	*12,912*	*8*	*654*	*18*	*9,916*	*63*	*44,945*

Table 9: Number of dams and area which can be irrigated as a result in the townships of interest. Source: DoI 2017


Pindaya Town
Hopong Town
Ayetharyar Town
Taunggyi Town
Shwenyaung Town
Aungpan Town
Nyaungshwe Town
Kalaw Town
Kyauktalonegyi Town
Naungtayar Town
Pinlaung Town
Legend
Off-season Irrigated Areas
Towns
Villages
Streams
lakes

GIS Remote Sensing Satellite Analysis

The irrigation extent was analysed using remote sensing satellite image analysis by an external consultant. Cloud free images for the period December to April were analysed using an established irrigation extent algorithm to identify cropping patterns based on vegetation greening and senescence, represented using NDVI and Landsat to provide better spatial definition. Additional masking algorithms were required to minimize the incorrect categorization of forests. Further details can be found in annex A.

The analysis estimates the total cropped area during the 2015/16 off-season to be 67,881 acres across the five townships of interest, as shown in Table 10. This does not differentiate between irrigated and residual moisture crops. Data from Taunggyi township Department of Agriculture presents a total of 17,760 acres grown in the 2016/17 off-season, of which 8,439 is by irrigation and 9,321 from residual moisture. The remote sensing analysis estimated 19,935 acres, suggesting the two data sources are generally aligned.

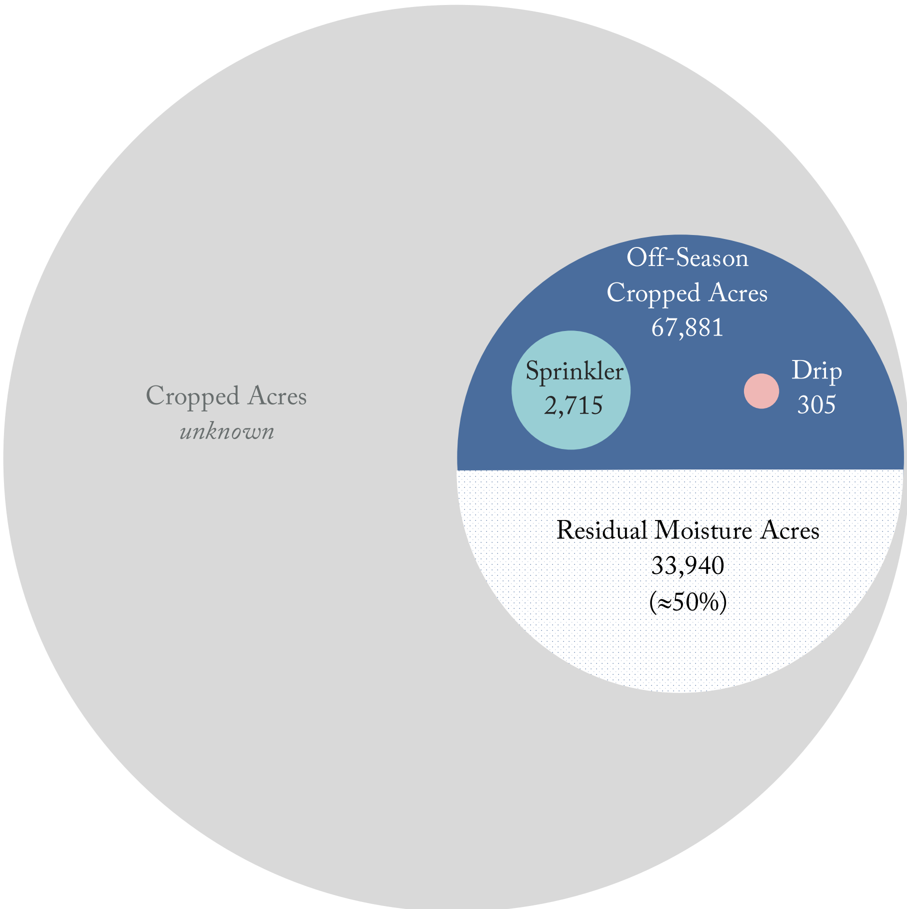


Figure 46: Townships of interest cropped and irrigated acres from remote sensing analysis. Sprinkler and drip irrigated areas estimated through extrapolation of field visits to ten irrigated villages.

Based on the data from Taunggyi DoA, it was assumed that half the off-season cropped acres are from residual moisture. While accurate for Taunggyi, further details are required from the other townships to establish a more accurate ratio across the area of interest.

To get a rough estimate of the extent of sprinkler and drip irrigation utilisation the data from the field visits to irrigated villages was extrapolated up as a relative percentage. The figure above can only be considered a rough estimate due to the small sample but provides a visualisation of the possible extent of sprinkler and drip usage.

Township	December 2015	February 2016	April 2016	Total Irrigation Area Dry season 2015/16	Department of Agriculture data 2016/17
Pindaya	2,309	366	445	2,978	
Kalaw	3,526	1,206	3,813	7,747	
Pinlaung	3,186	3,102	4,831	10,174	
Taunggyi	10,295	13,035	3,708	19,935	17,760
Nyaungshwe	16,207	21,603	24,470	37,772	
Total	**29,689**	**37,740**	**33,009**	**67,881**	

Table 10: Off-season cropped area extent from remote sensing analysis

As shown in Figure 47, the cropped area in Taunggyi reduces significantly at the end of the off-season. This could suggest that a single crop cycle is predominantly practised. This could be due to a relatively greater proportion of residual moisture cropping in the first half of the off-season, or that irrigation water sources or crop choices do not facilitate two crop cycles. By contrast the cropped area in Nyaungshwe increases. The reason for this requires further insight, but could be due to cropping on new wetted land as the boundary of the lake recedes. The pattern for Kalaw suggests a possible double crop cycle approach with less greening in February due to early stage of the second crop. The cropped area in Pindaya reduces suggesting reducing irrigation water supply and slightly increases in Pinlaung.

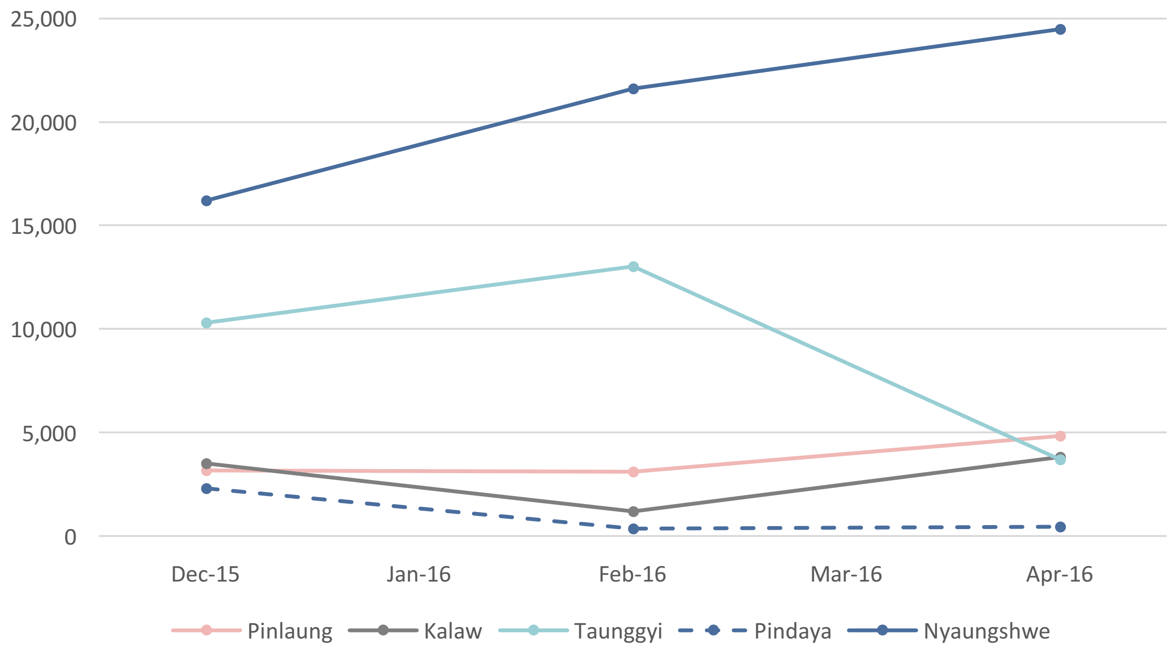


Figure 47: Change in extent of cropped area in acres during the 2015/16 off-season from satellite analysis.

Combining the off-season cropped areas satellite analysis map with the newly developed stream map enables the investigation of the proportion of cropped areas within varying proximities to a stream as shown in Figure 48: Cropped areas within proximity to a steam, pond or lake below.

It could be presumed that the majority of cropped areas within close proximity to a stream or water body are primarily grown by irrigation rather than residual moisture. It was found that 41% of off-season cropped areas are within 500 feet of a stream or water body, 63% within 1,000 feet and 76% within 1,500 feet. Within the project area this represents almost 28,000 acres within 500 feet.

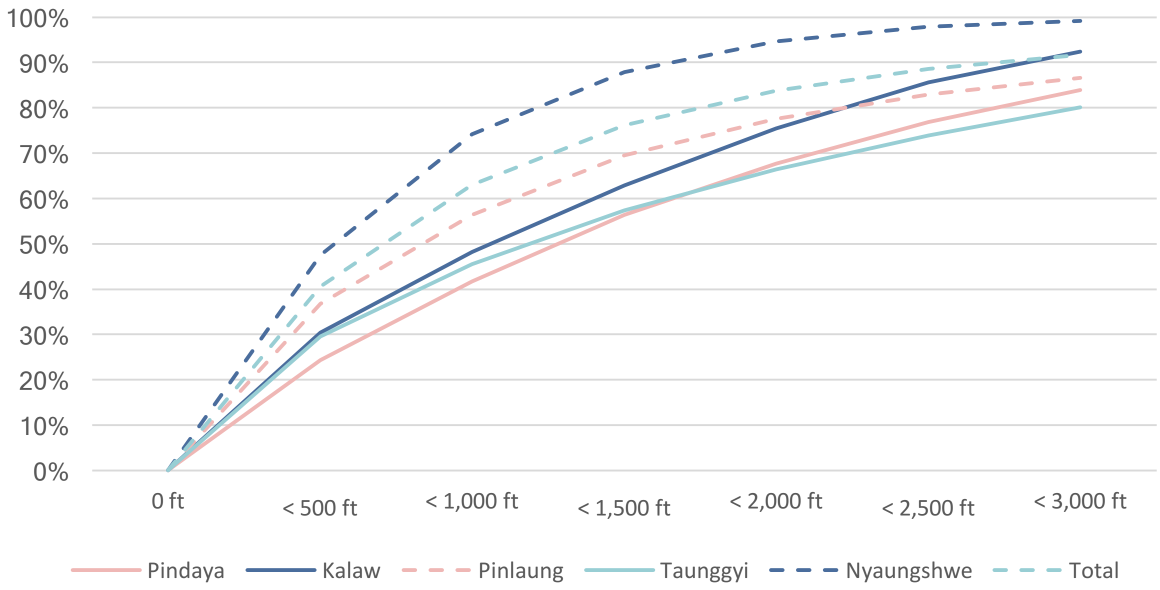


Figure 48: Cropped areas within proximity to a steam, pond or lake

Satellite image analysis of this type should be considered as an estimate. Misclassification of greening can occur, with either cropped areas not being picked-up or non-cropped areas being incorrectly classified. The area of interest has many hills and forests which proved challenging for existing algorithms. As a result, additional algorithms were required to reduce the misclassification of forests as cropped areas. It would be useful to gather further cropped area data from the Department of Agriculture for the other townships.

The GIS map files for streams and off-season cropped areas are available from Mercy Corps.

Water Utilization

This chapter looks at how well farmers are currently utilizing existing water and improved irrigation options. We look at the main reported barriers to both, which are predominantly access to credit and the risk of crop selling price variation. In this chapter we also present the main types of pumps, pipes and irrigation systems that farmers are purchasing in the local markets and find that generally farmers are making reasonable choices. We show that fuel for pumping water normally costs around $100 per acre per crop cycle. Hydraulic models are created and show that in theory most farmers should be able to use existing pumping equipment if upgrading to drip systems.

Utilization of existing springs and streams

On the basis of the irrigated villages visited the majority of villages are already utilising their available water within what can be considered practical and financially feasible. A general pattern of increasing irrigation was observed. Initially a wealthier farmer, usually with a larger plot, decides to start irrigating. This is usually triggered by seeing a system in another village, which they set out to replicate. After one off-season a few other wealthier farmers, having seen the benefits, follow suit. Two to four years later the majority of farmers have replicated, or improved, the initial set up and are also benefiting from off-season irrigation. Those who are 'left behind' either have land further away from the water source making utilisation more expensive, have a small plot making the cost benefit ratio less attractive, or are less wealthy and unable to afford the required capital.

		Available water is:			
Township	Village	significantly under-utilised with significant potential for increasing the irrigated area	partially utilised with significant potential to increase the irrigated area	mostly utilised with some potential to increase the irrigated area	well utilized within what is financially practical
Kalaw	Nang Ong Ywar Ma		●		
Kalaw	Baw Di Kone				●
Taunggyi	Pin Lon				●
Taunggyi	Hti An	●			
Nyaungshwe	Taung Poet Gyi				●
Nyaungshwe	Taung Gyar		●		
Pinlaung	Naung Lin				●
Pinlaung	Inn Gaung				●
Pindaya	Zaw Gyi		●		
Pindaya	Htoe Pon			●	

Table 11: Utilisation of existing available water in visited irrigated villages.

Of the twelve villages visited, ten had access to some form of irrigation water in the off-season. Of these, half can be considered to be fully utilising the available water within what is financially practical. For this analysis prospecting for uncertain deep groundwater is not considered financially practical. One village, Htoe Pon, was considered to be mostly utilising available water with roughly just 10% of households unable to afford the setup costs, mainly due to small plot sizes. Three villages were classified as partially utilising available water and with significant potential to increase the irrigated area. Just one village, that before the MVMW program only grew with residual moisture, was classified as significantly underutilising their available water.

Nang Ong Ywar Ma village in Kalaw township. Despite having plentiful water resources from the one of the biggest springs in Kalaw, until the past couple of years grew almost nothing in the off-season. After learning about pumping systems and pipelines from other villages they started installing their own systems and now irrigate about half of the possible land, about 50 acres. They use pipelines of up to 2,500ft in length, uphill and some requiring 2 stage pumping.

It should be noted that under-utilisation of water by an upstream village does not necessarily mean under-utilisation of the water resource as a whole. It is quite possible that overall all available water is used and that by following the streams, the point at which flows become unusable could be identified. As such, while any program to facilitate new pumping systems will be able to display project benefits, it could be at the equal expense of a downstream farmer. A cautious approach would be required.

What are the main barriers?

For the villages where water is not already well utilised, the main barrier reported was a lack of available capital or access to affordable credit. This was closely followed by and often intrinsically linked to the risk of low selling prices, particularly a fear of a crop being financially unviable to harvest. Although this risk applies to all farmers, those who have not yet invested are usually poorer and therefore have more to lose. It may be the case therefore that access to credit alone would only have a partial impact unless the terms are flexible to cases of detrimental crop selling conditions.

Some of the five villages already well utilising their water may still have ways to increase the quantity of water available. Baw Di Kone in Kalaw requested government support to create a new dam and reservoir in order to increase their off-season irrigated area. Taung Poet Gyi in Nyaungshwe could improve their artesian well, but would require technical support, possibly from the government. Pin Lon in Taunggyi may potentially find more shallow spring ponds. These situations are very specific and not included in the table of main barriers below.

		Reported main barrier/s to increasing usage of water			
Township	Village	Risk of low selling price or unviable crop	Access to funds or affordable credit	Waiting for proof of cost benefit	No knowledge of the solution
Kalaw	Nang Ong Ywar Ma	🔴	🔴		
Taunggyi	Hti An		🟡	🔴	
Nyaungshwe	Taung Gyar		🟡		🔴
Pindaya	Zaw Gyi	🟡	🔴		
Pindaya	Htoe Pon	🟡	🔴		

Table 12: Reported main barrier to increasing water utilisation in villages where it is not already well utilised. Primary barrier in red.

Searching for new water

Of the twelve villages visited, two had sufficient spring water and no need to explore groundwater. Of the remaining villages three of ten had tried to find groundwater, with varying success. The general trend appears to be that one of the wealthiest farmers hires a local drilling contractor with some agreement for risk sharing. If successful and with adequate yield other farmers with available cash follow over the next years, with the lower income farmers continuing to be unwilling to take the risk or unable to afford. In villages with no or less access to water, and particularly smaller landholdings, there is less or no available income to risk prospecting for groundwater and so they remain without water. All villages visited that had developed groundwater already had access to springs or streams resulting in higher farming incomes, existing evidence of the cost benefit of off-season farming and combined more willingness for some farmers to take the risk.

As discussed in a previous section groundwater prospecting can be a risky endeavour, with unknown final water levels (and therefore pumping costs) and unknown yields. While some wealthy farmers who take the risk will find cost benefit, others will take a loss in the process. More informed drilling with geophysical testing equipment is not currently a realistic option, but drilling practises could be improved with the aim of higher success rates.

Figure 49: One mile away from a village visited with no irrigation water, a wealthier farmer is finishing the installation of a new deep (200ft) tubewell (static water level of 40ft). He agreed with a local contractor that if it failed he would not have to pay anything, only provide food for the workers. The borehole cost 600,000 MMK ($480), the pond 500,000 MMK ($400) and a second-hand engine and air compressor 400,000 MMK ($320). The total cost was 1,500,000 MMK ($1,200).

The tubewell has an estimated flowrate of 1.9m^3/hr (418 imperial gallons) and he hopes to irrigate three acres. He was motivated by higher vegetable prices in the off-season. If successful we estimate that he will be able to make a profit of at least 700,000 MMK ($560) per acre, a total of 2,100,000 MMK ($1,680) for all three acres.

With a payback period of less than one season and significant future income potential this clearly represents an excellent investment.

Taunggyi: U Powet is a farmer from Baw Di Kone village. Like the other farmers in his village he grows corn during the rains but has not grown vegetables other than for home use. After learning from the MVMW program and visiting another village he realised that it could be profitable to use the local stream to grow vegetables in the off-season. In November 2016, he spent 250,000 MMK cash to buy pipes which he has set up to irrigate 2 acres, including some with local sprinklers. He doesn’t need a pump as he can use gravity but he prefers pipes to earth canals as he says they don’t waste water so he will be able to irrigate more land. If this season goes well he plans to invest some of the profit to slowly extend his irrigation network.

Sprinkler and Drip Utilization

Of the ten irrigated villages visited, five were currently using sprinkler systems. Based on the farmer reported acre figures, this represented just over 8% of the irrigated land of these villages. Nearly all sprinkler systems witnessed were PVC pipe type locally procured and set-up directly by farmers. One further village had tried sprinkler systems but since stopped. As with pump and pipeline systems the sprinkler configurations appeared to occur in local clusters based on the practise developed by the early adopter/s.


Figure 50: Typical PVC sprinkler system

Three of the irrigated villages were currently using some level of drip irrigation. Based on the farmer reported acre figures, this represented just under 1% of the irrigated land of these villages. Three different drip systems were observed, by Prime, Yetagon (the outward facing brand of Proximity Designs products) and an unbranded drip tape purchased from Naypyitaw. Prime drip systems are not understood to be commercially available, instead provided on credit to Prime contract farmers. The Yetagon drip system is an older type with non-turbulent flow and gravity supply. The few farmers who had either previously tried it or heard of it had not been impressed due to frequent blocking of the drip micro-tubes. The local suppliers only sell a small volume.

Three farmers from two villages in Pindaya had sourced and purchased an unbranded turbulent flow drip tape from Naypyitaw, which in appearance looks the same as the Prime tape seen in the field but with thinner walls.

Further details and prices are available in the 'sprinkler and drip equipment' chapter that later follows.

What are the main barriers?

The barriers to increased uptake of sprinkler and drip systems were more varied than the barriers to increased water access. The benefits of moving from rain-fed to off-season irrigation are clear to most famers, with access to funds or credit, along with the risk of fluctuating selling prices, the main barriers. The second 'step-up' to improved irrigation is a more difficult concept to sell. As discussed with Asia Irrigation, the initial step-up to drip irrigation can be uninspiring, with the more exciting gains coming once the next step is made to fertigation, something that does not appear to currently be happening in the project area.

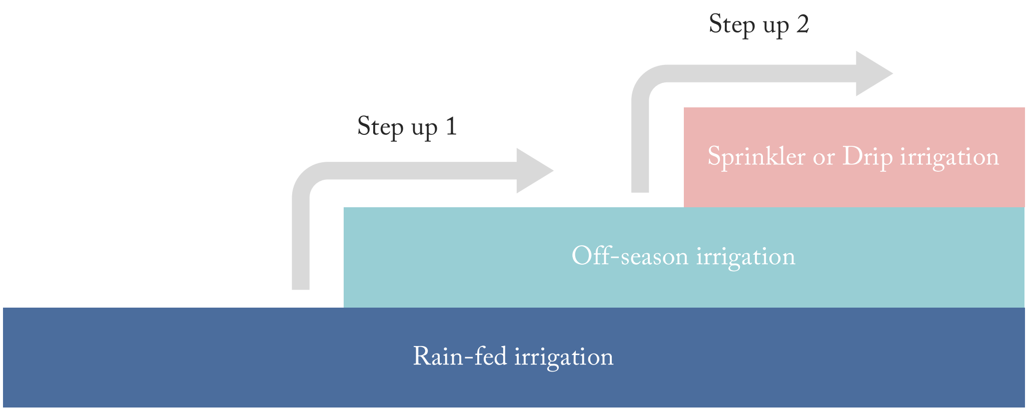


Figure 51: The two steps to improved off-season irrigation from rain fed only

With most villages not having seen drip systems in operation their opinion was either absent or based on word-of-mouth, usually relating to frequent blocking of the drip pipe/tape. Farmers did not generally have an understanding of the impact that drip could have beyond reducing diseases and water consumption.

The three main barriers reported by farmers were (1) uncertainty regarding the return on investment, (2) the risk of low selling prices, and (3) access to funds or affordable credit. These barriers are interdependent. Access to affordable credit alone seems unlikely to lead to notable new drip uptake. Likewise, neither is creating more awareness and certainty over the potential benefits and returns. In most villages farmers would refer to someone who had to leave their crop unharvested due to falls in selling prices. This fear and subsequent risk aversion will likely continue to limit the uptake of sprinkler and drip systems. Farmers reported that they would be interested in affordable credit for drip systems but would prefer payment to be spread over ideally two seasons.

	Village	Risk of low selling price or unviable crop	Access to funds or affordable credit	Uncertainty of the return on investment	Not convinced drip will work
Kalaw	Nang Ong Ywar Ma	●	●	●	
Taunggyi	Pin Lon	●		●	
Taunggyi	Hti An	●	●	●	
Nyaungshwe	Taung Poet Gyi			●	
Pinlaung	Naung Lin		●		
Pinlaung	Inn Gaung			●	●
Pindaya	Zaw Gyi	●	●	●	
Pindaya	Htoe Pon		●		

Table 13: Reported barriers to increasing sprinkler and drip irrigation systems.

In addition to the information gathered through the field visits, feedback was provided to the Mercy Corps team based on the existing drip irrigation demo plots established in partnership with Asia Irrigation. Disadvantages reported included lack of even distribution, poor water quality blocking emitters even with the filter, no time to run the pump, high cost, high level of skill required and a perception that the land needs to be level. The advantages mentioned included reduced water consumption, reduced weeds and less labour.

Figure 52: Prime drip system supplied water filter with hydro-cyclone, disk filter and pressure release valve.

Figure 53: Prime drip irrigation in use

Figure 54: Unbranded Naypyitaw drip tape in use with sweet peppers

Water Pumping Equipment

While there is a range of manufacturers available in the local markets, the types of pumping equipment are limited and the products used fairly consistent across the project area. For pumping from surface water the majority of farmers use Chinese made diesel engines connected via belt drive to a water pump. The size of the engine and pump vary based on local practises. The use of cheaper all-in-one petrol pumps was only seen where a small plot was being irrigated or where water had already been pumped via diesel pump to a field side pond. Electric pumps, including solar, are not used and not available in the required sizes in the local market. All deep tubewells observed used either direct suction pumping or, more commonly, a Chinese diesel engine connected by belt drive to an air compressor for pushing the water up and out. We did not see any instances of borehole submersible pumps with generators.

January to March were reported by suppliers as the peak season for sales of non-rice irrigation pumps.

Pumps

Diesel and Petrol Pumps

The most common set-up seen during field visits was a 10-12HP diesel engine with either the 2" SU50 or the 3" SU80 (or other equivalent brands). Farmers who have been irrigating for several years reported that previously the Thailand made Kato brand was popular but that it is no longer available as cheaper Chinese products pushed it out of the market. The 'SU' brand of pumps was found in all suppliers visited, with the 'Jieneng' brand also commonly available but not seen in use in the field.

Pumps made in Myanmar were not seen during village visits but were reported by traders to be increasing in popularity. Most shops stocked both Chinese and Myanmar pumps.

The recommended combination of engine and pump, as per the pump manufacturers power requirement, is shown below.

Pump outlet size (inches)	Model	Engine power		Average pump price at suppliers visited, without engine (MMK)
		Manufacturer recommendation	What farmer's buy and use	
2	SU50 (China)	5.5 HP	5 – 6 HP	36,000 ($29)
2	Jieneng NS-50 (China)	5.0 HP		47,000 ($38)
2	Kato SKP-A50S (Thailand)	7.5 HP		-
3	SU80 (China)	6.5 HP	9 – 12 HP	44,000 ($35)
3	Jieneng NS-80 (China)	6.7 HP		68,000 ($54)
4	SU100 (China)	13 HP	12 – 13HP	76,000 ($61)
4	Jieneng NS-100 (China)	10 HP	22 HP	84,000 ($67)

Table 14: Common pumps in the project area. their associated engine power requirements and average prices.

Diesel engines with two pump units in series were seen in a couple of villages as a way to double the head (pressure), both using SU80 pumps, one with a 12HP and the other a 22HP engine. Alternatively, the supplier in Aung Ban stocked a 6 stage Myanmar made diesel engine powered pump model with a maximum head of 125m and cost of 240,000 MMK ($192). It is reportedly purchased only by farmed in the Kalaw area to pump up more inclined land.

The table below shows the average price for the required diesel engines and other items required excluding the delivery pipe. Smaller 5-6 HP engines were not found in the suppliers visited.

Diesel Engines	Average Price (MMK)	Associated Items	Average Price (MMK)
9-10 HP Cementhai	405,000 ($324)	Base for engine and pump	10,000 ($8)
11-12 HP AMEC	350,000 ($280)	2" suction pipe, 30ft	22,500 ($18)
22 HP AMEC	400,000 ($320)	3" suction pipe, 30ft	45,000 ($36)

Table 15: Common diesel engines with their average price and required associated items

Therefore, the total cost of the most common diesel engine powered pump set ups, excluding pipe are as follows:

Item	Specification	Quantity	Average Price Range (MMK)
Diesel Engine	9 – 12 HP (1-1.5 litre/hr fuel consumption) or, 22 HP (2 litre/hr fuel consumption)	1	350,000 to 420,000
Pump	SU80 or NS-80 3" model	1	44,000 to 68,000
Pump Base	-	1	10,000
Suction pipe	3" flexible hose with wire	30 ft.	45,000
Fittings	Foot valve, control valve, pipe connection	-	20,000
		Total	**469,000 to 563,000**

Table 16: Cost for a typical diesel engine and pump set-up based on local market prices

For the all-in-one petrol pumps there was greater variation in brands available, all Chinese. Popular brands included Doyen, Leo and Yakuza.

Model	Average pump price at suppliers visited (MMK)	
	2" model	3" model
Petrol Yakuza brand	125,000 ($100)	135,000 ($108)
Petrol Doyen brand	117,000 ($94)	125,000 ($100)
Petrol Leo brand	157,000 ($126)	175,000 ($140)

Table 17: Common petrol water pumps and their prices in the local market

During the supplier visits we asked for any relevant brochures or catalogues that would include pump curve details. Suppliers also opened boxes to look for pump curves in the instruction manual. In most cases pump curves were not available. The Myanmar and Chinese Jieneng manufacturers were contacted directly by telephone but stated that they do not have pumping curves. However, we were able to obtain curves for the SU models of diesel engine powered pump and the Leo petrol pumps. A curve for the 6-stage pump was produced as an estimate based on available data on the pump plate. The details are shown on the following page including the effective curves for using two pumps in series or parallel.

Only the largest supplier visited, Good Brothers, offered any form of warranty with one year for the diesel engines.

Figure 55: (left) A range of typical pumps which farmers power with diesel engines. (right) A typical 2" petrol pump.

Fuel Costs

Fuel prices in Myanmar are low. Although not subsidised, with a commercial tax rate of only 10% the pump price of diesel and petrol are low by global standards. In the past 6 years the price per litre has not passed 1,000 MMK ($0.80) and is currently less than 800 MMK ($0.64 per litre, $2.42 per US gallon)(The World Bank, 2017).

The pumping time required will vary based mainly on the height of the field from the water source and to a lesser extent on the length of the pipeline. New 2" petrol pumps will consume about one litre of fuel per hour, rising to about 1.5 litres per hour for the 3" models. For diesel engine pumps the manufacturer data shows a fuel consumption at full power of 1.0, 2.0 and 2.5 litres per hour for 6, 12 and 22 HP units respectively. However, during the field visits farmers reported fuel consumptions of between 1.0 to 1.5 litres per hour for

12 HP engines, suggesting that either they are not running the pumps at full power or their estimations are optimistic.

For most farmers, with a required total head less than 20m, pumping to furrow irrigation or a temporary holding pond requires between 45 to 60 minutes of pumping per day at peak demand; with a 12HP diesel engine and SU80 pump. The table below shows the total crop pumping demand per acre for two crops.

	Small vegetables (FAO)	Tomatoes (FAO)
Total irrigation requirement of crop if planted on 1st Dec in Taunggyi*	237 mm	416 mm
Total irrigation requirement of crop per acre in cubic meters	957 m^3	1,683 m^3
Assumed irrigation efficiency	50 - 60 %	50 - 60 %
Total irrigation pumping requirement for crop per acre	1,595 to 1,914 m^3	2,805 to 3,366 m^3
Assumed pumping rate of 12HP diesel engine with SU80 and 19m total head	30 m^3/hr	30 m^3/hr
Total hours of pumping required for crop	53 to 64 hours	94 to 112 hours
Fuel usage of diesel engine	2 litres / hour	2 litres / hour
Cost of diesel per litre	800 MMK	800 MMK
Total cost of diesel fuel per acre of crop per season	**85,000 to 102,000 MMK/acre ($68 – $82)**	**150,000 to 179,000 MMK/acre ($120 - $143)**

Table 18: Diesel costs per acre for two crops. *Crop irrigation requirement calculated in CropWAT software based on climatic data from Taunggyi weather station.

Generally, farmers were reporting spending about 100,000 MMK ($80) per acre for fuel costs which correlates well with the calculated estimate for small vegetables.

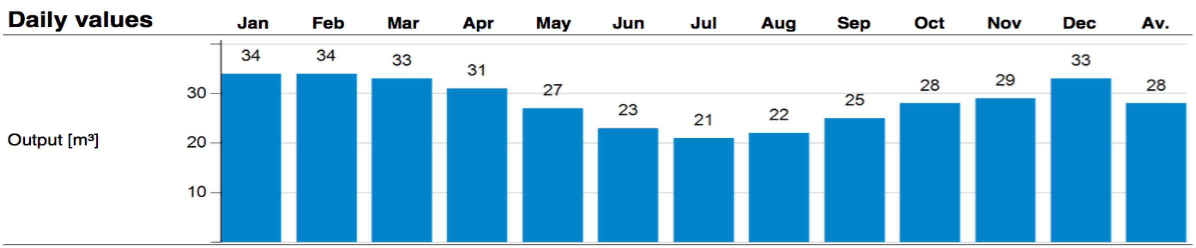
Electric Pumps

Electric pump sets are not used by farmers for irrigation. As such suitable pumps were not found in the market. One model, the Leo APm75, sold for other industrial purposes was found in Heho with a price of 76,000 MMK ($61). It is included on the pump curve graph for illustrative purposes.

Solar Pumps

Solar pump set ups are not available in the local market. While the separate components could be purchased and assembled it is not being done. The low cost of fuel would likely not make such a set up worthwhile financially.

For conceptual analysis purposes an example of a Lorentz solar pumping system is shown below based on a price obtained from the Myanmar supplier based in Thailand. The flowrates are based on a total head of 30m at modelled by Lorentz for solar conditions at Taunggyi (20° North; 97° East). If the required head was reduced to 20m the daily flow would increase to around 42m^3/day between December and March. This equates to a typical irrigation area of around 1.5 acres of tomato or 2 acres of small vegetables at peak demand.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Energy [kWh]	9.1	9.3	9.1	8.2	7.0	5.9	5.5	5.5	6.1	6.8	7.3	8.3	7.3
Irradiation [kWh/m²]	6.6	6.9	6.9	6.2	5.2	4.3	4.0	4.0	4.5	4.9	5.2	5.9	5.4
Rainfall [mm]	0.20	0.13	0.30	1.4	5.2	6.4	7.0	9.3	8.6	5.1	2.1	0.27	3.8
Ambient temp. [°C]	16	20	24	26	24	23	23	22	22	21	18	15	21

Figure 56: Solar pump design table for Taunggyi

Pricing and specification for the above solar system are as follows:

Item	No.	Total Price (MMK)
Lorentz PU1800 CS-F4-5 1.25" Pump	1	1,455,000
Lorentz PS2-1800 Pump controller unit	1	806,000
Lorentz dry run sensor	1	66,000
Lorentz pipe water sensor	1	193,000
Lorentz pressure switch	1	62,000
Lorentz surge protector	1	22,000
Lorentz supplied Onesto DC breaker	1	17,000
Lorentz supplied Onesto DC surge protector	1	85,000
Locally purchased 150 w solar panels	10	900,000[6]
	Total	**3,606,000 ($2,885)**

Table 19: Solar pump cost

Based on local inquiries in Yangon a Chinese equivalent pump, including all required controllers and accessories would cost around 650,000 MMK ($520) making a reduced total of around 1,500,000 MMK ($1,200) with panels. This represents around 1,000,000 MMK ($800) more than a diesel pump set up. With average fuel cost of 100,000 to 150,000 MMK ($80 to $120) per season the Chinese solar pump system would have a pay-back period of 7 to10 years, likely longer than the design life of the pump and therefore not financially feasible.

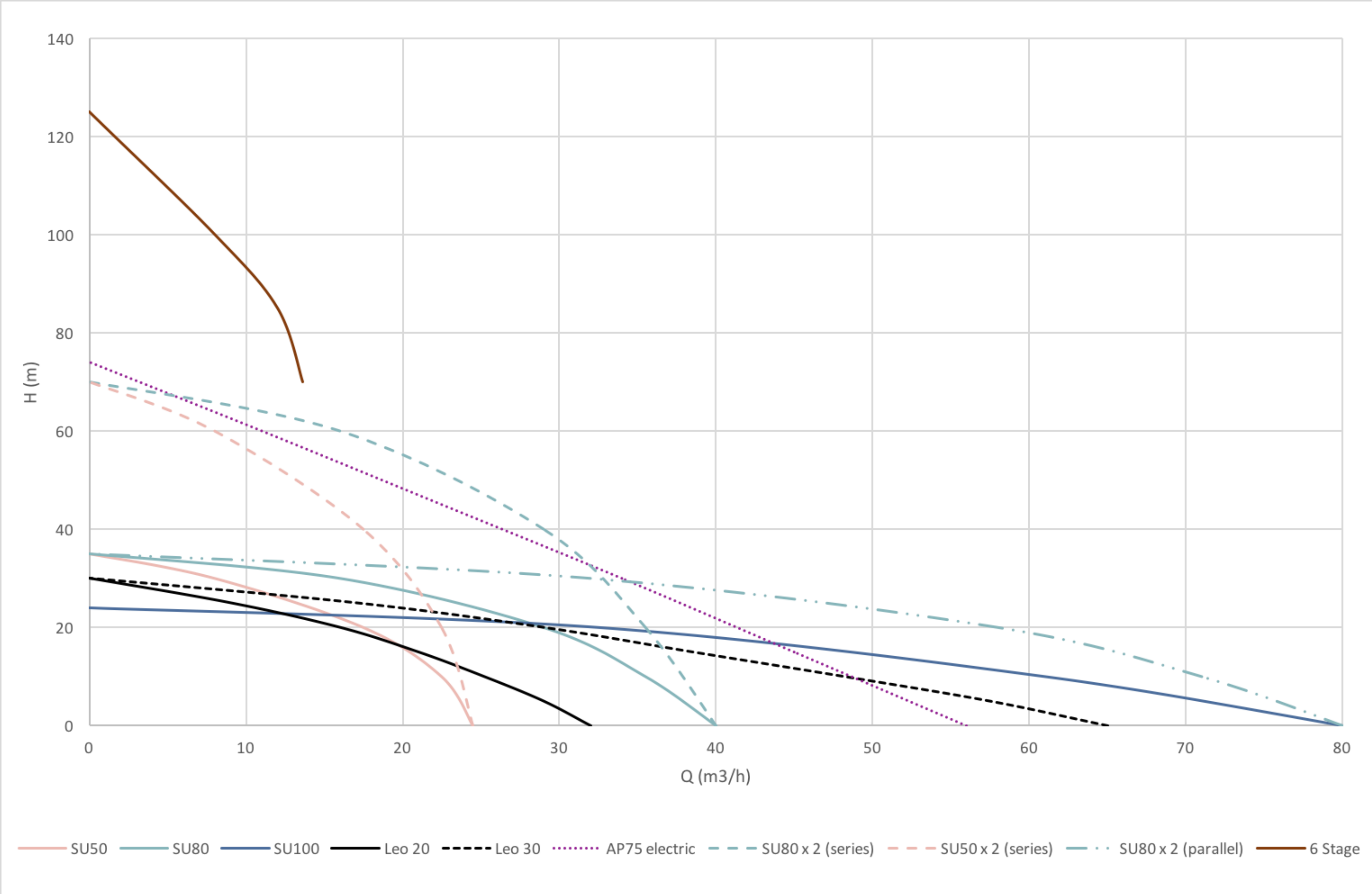
Yetagon do have a recently released solar pump product which online information states retailing around 500,000 MMK ($400) for the complete set up (Goudarzi, 2016). During the meeting with Proximity, the producer of Yetagon products, they were unable to recall the exact price but thought it to now be around 700,000 MMK ($560). This is not a directly comparable product to the solar pumps mentioned above which run with 1500 w panels and over 50m^3/day at low heads. The Yetagon system is more suitable as a replacement for existing treadle pump application and delivers around 13m^3/day at low (7m) head. This equates to being able to irrigate around roughly 0.5 acres of tomato or 0.6 acres of small vegetables at peak demand. However, such a low head environment is rare in the project area and the submersible pump type is not directly suitable for pumping from streams, although it could theoretically be modified to a dewater style pump with screen. There was no technical data available from Yetagon so the area that could be irrigated with higher head requirements cannot be calculated or estimated.

Hydraulic Ram Pumps

Theoretically, commercial or locally made hydraulic ram pumps could provide a low-cost fuel free pumping solution to a few areas, such as sloping land with streams. However, this technology is not currently used in the project area and the considerations for constructions are complex. As the flowrates would be low the water would need to be stored in an intermediary pond before using a small pump to irrigate.

Figure 57: (following page) Pump curves for typical pumps found during the field visits.

[6] Based only on one supplier in Aung Ban. Could likely be cheaper from larger markets and with larger panels.


H (m)
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
Q (m3/h)
SU50
SU80
SU100
Leo 20
Leo 30
AP75 electric
SU80 x 2 (series)
SU50 x 2 (series)
SU80 x 2 (parallel)
6 Stage

Pipe

Farmers pumping up to a few hundred feet, or those who were testing out pumped irrigation for the first time had a preference for the cheaper PVC layflat hose, either 2” or 3” diameter. Villages with established irrigation practices has installed underground solid PVC pipelines, either 2” or 3” diameter. Larger 4” diameter pipe is not used. There are three classes of PVC pipe available in the market, class 5, 8.5 and 13.5. The number represents the maximum pressure that the pipe can handle in bars. Suppliers reported that the most common size and class purchased by farmers is either 2” diameter class 8.5 or 3” diameter class 5.

Based on the pump curves a farmer using single stage pumping can theoretically use class 5 pipe as the maximum pump pressure is not more than 4 bar. For famers using two pumps in series class 8.5 is required and for farmers purchasing the 6-stage pump class 13.5 is required.

The prices for PVC layflat and standard PVC pipes are as follows.

	Average price per 100 feet (MMK)			
Pipe Size	Layflat pipe	PVC Class 5	PVC Class 8.5	PVC Class 13.5
2”	23,000 – 28,000 ($18 - $22)	21,100 ($17)	30,850 ($25)	46,100 ($37)
3”	31,000 – 37,000 ($25 - $30)	31,950 ($26)	61,100 ($49)	100,000 ($80)

Table 20: Price of PVC pipe in Aung Ban market.

The layflat hose found in the market is unlikely to last more than 2 to 3 years. By comparison, correctly constructed solid PVC pipelines can last over 20 to 50 years if not damaged by external forces.

Figure 58: (left) Layflat PVC pipe in 2, 3 and 4” found in the local market. (right) Typical PVC pipe.

Are farmers choosing the correct pumping equipment?

In all villages visited farmers reported selecting engines, pumps and pipes based on what they have seen from other nearby farmers. As such there seems to be clusters of specific practices which vary slightly in terms of engine power, pump model and pipe diameter (for equivalent pumping distances). The early adopters, who subsequently influenced their cluster, reported using a trial and error approach. This approach worked to ensure that systems were not undersized but did not necessarily identify oversizing or optimal configurations for efficiency; although oversizing does allow flexibility for future expansion at a slightly higher initial set up cost.

Suppliers reported that when farmers come to buy pumping products that they have already decided what they want and do not seek technical support.

U Hla Baw owns 20 acres of land and grows corn during the rains. After Mercy Corps showed him how a nearby village was able to make profit from growing vegetables in the off-season he was encouraged to try himself using water from the local stream. He wasn't quite sure what equipment to buy so copied what he had seem other farmers doing and invested 450,000 MMK ($360) cash to purchase a 3" pump and 300 feet of layflat pipe. This off-season he is growing one acre to test it out and if all goes well plans to scale-up next year.

Sprinkler and Drip Equipment

Sprinkler systems

All sprinkler systems seen during the field visit were locally made systems using PVC pipe and local Chinese made sprinkler heads. In the market one other system, made by Yetagon, was found.

Local PVC: The exact quantities and pricing depends upon the pumping pressures and therefore the water dispersal radius. The common spacing observed during the field visit was 12 feet or 18 feet. The table below shows the price of materials only for a typical one acre plot requirement. The price obtained by Mercy Corps from a Yangon based supplier (Marlarmyaing company) is compared against what a farmer would spend through purchasing directly in the local market. These prices do not include a pump or any transport costs.

Description	Qty	Marlarmyaing company (Yangon)		Local Aung Ban Suppliers	
		Unit Price (MMK)	Total Price (MMK)	Unit Price (MMK)	Total Price (MMK)
SP II (Sprinkler)	340	400	136,000	500	170,000
2" PVC Pipe (19')	18	8,000	144,000	5,600	100,800
1.5"PVC Pipe (19')	34	5,000	170,000	3,800	129,200
1" PVC Pipe (19')	210	3,000	630,000	2,300	483,000
		Total	*1,080,000 ($864)*	*Total*	*883,000 ($706)*

Table 21: Cost of local PVC sprinkler system per acre.

Yetagon: The main supplier in Heho reported that Yetagon products are not popular and they normally sell around 4 to 5 sprinkler units per month. The supplier in Taunggyi only sells Yetagon sprinklers to architectural gardening projects and the supplier in Aung Ban reported selling around 25 units per month. This scales up to an estimated 36 acres of coverage per year only. The suppliers quoted 55,000 MMK per 0.1 acre; 550,000 MMK ($440) per acre.

Drip systems

During the field visits three types of drip systems were found, Yetagon, Prime and an unbranded type purchased in Naypyitaw (NPT).

Asia Irrigation is currently running and establishing new demo drip systems in collaboration with Mercy Corps and East West Seed. They are in the process of setting up a supplier in Myanmar. The price in the table below was provided by Asia Irrigation as a good indication of the likely selling price. The system is the modern turbulent flow type. They provide filtration systems and can support set-up and training.

Prime systems are not available on the open market, instead provided on credit to Prime contract farmers. The modern systems come complete with hydro-cyclone and disk filters. Prices were provided by two farmers who purchased the systems for potato contract farming, not directly by Prime.

NPT: The unbranded system from Naypyitaw was observed in two villages in Pindaya. Visually the drip pipe looks almost the same as the Prime system but with thinner walls. It cannot be purchased locally. The prices shown in the table below were quoted by the farmers who purchased the systems.

Yetagon[7] sells an older style drip system based on a system originally designed by iDE. It is a gravity flow system that requires setting up a header tank. It is designed for small (1/8th to ¼ acre) plots that are relatively level. The systems cannot easily be joined together to scale up for larger plots. The main supplier in Heho reported that Yetagon products are not popular and they normally sell around two drip sets per month. The supplier in Taunggyi reported selling one drip unit in the past year and the Aung Ban supplier around 3 per month. We believe that these are the only 3 suppliers in the project area. This scales up to an estimated total of only 6,100 ft of drip per year (0.7 acres), which corresponds with the poor perception that all but one farmer had of the Yetagon drip product. Each set is reported to cost 45,000 MMK ($36) and can irrigate up to ¼ acre (Proximity Designs, 2017). It was reported that Yetagon sold just over 8,000 drip units since the launch

[7] The external brand name of products produced and marketed by Proximity Designs

of the original version in 2004, which represents a total maximum coverage of 2,000 acres nationally, (Proximity Designs, 2017).

Mikki drip tape is made in Thailand and imported by a distributor. It is not currently available in shops and must be purchased directly from the supplier based in Mandalay. It is used for small scale homestead vegetable farming by Terre des Hommes in the central dry zone and was recommended for consideration.

Drip Manufacturer	Price per acre (vegetable crop) MMK	Notes
Prime	1,800,000 1,400,000	Two different prices quoted by Prime contract potato farmers – includes all accessories and filters.
Asia Irrigation	900,000 ($720)	Estimated as the Myanmar price. Includes filter and fittings Installation +$70 up to 1000m2 ($80 for 1500m2)
Mikki (Thai)	532,000 ($426)	80,000 per 3000ft + 70,000 per 300ft main pipe Does not include filter, fittings.
Unbranded (Naypyitaw)	400,000 ($320)	Farmer quoted 400,000 / acre Drip tape and main pipe only
Yetagon (Proximity)	336,000 ($269)	42,000 per 1000ft quoted. (single line required) Includes basic filter.

Table 22: Prices of different drip systems per acre based on 44 beds per ¼ acre and 2 lines per bed = 17,320 ft per acre plus the main line. Yetagon requires one line. No prices include installation, some include filters and fittings.

Suitability of existing pumps and pipelines

Information provided by Asia Irrigation recommended that double line drip systems, as is most common for vegetables, with usual bed spacing requires a flowrate of 42.5m^3/hour at a system entry pressure of 1.2 Bar (12m). This information was used, with +10% design factors, to establish the requirement per quarter acre and combined with the pump curves of commonly used systems to produce Figure 59 below.

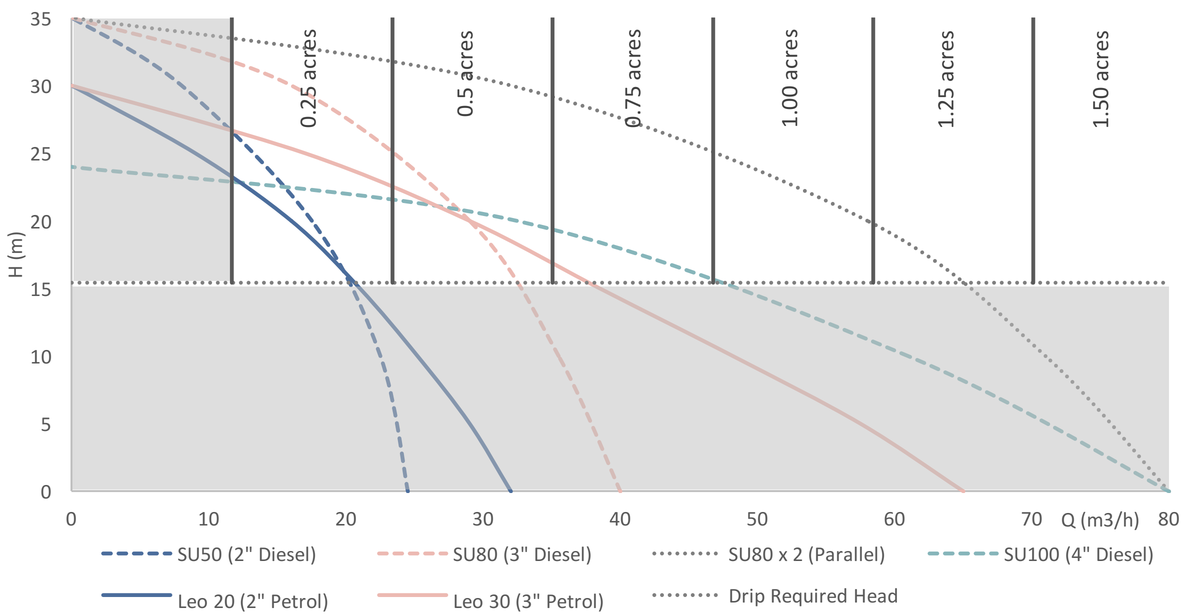


Figure 59: Commonly used pumps and their suitability for field side pumping for drip irrigation. Required flowrates based on Asia Irrigation recommendation of 42.5m3/hr/acre with a +10% design margin to factor in more realistic real-life pump performance. Head assumes field side pumping with 12m for the drip system, 2m suction head and a +10% design margin.

During the field visits no farmers were observed using a field side pond and double pumping. The drip systems observed generally had about a 30 to 152m (100 to 500ft) fairly flat run from the water source to the field using usually 2" pipe. As they pump direct from streams which can be as deep as 3 to 5m below the pump level the below graph assumes a 4m suction head and 2m lift providing a total static head of 6m.

The graph below shows scenarios of direct pumping to drip with a 500ft or 1,000ft pipeline and 6m static head. Note that the system curves on the graph start at the required minimum flowrate for the corresponding acres and do not extend beyond the point at which >2.5m/s velocity would be reached as per general hydraulic design. A conservative Hazen Williams of 130 was used for the PVC pipe.

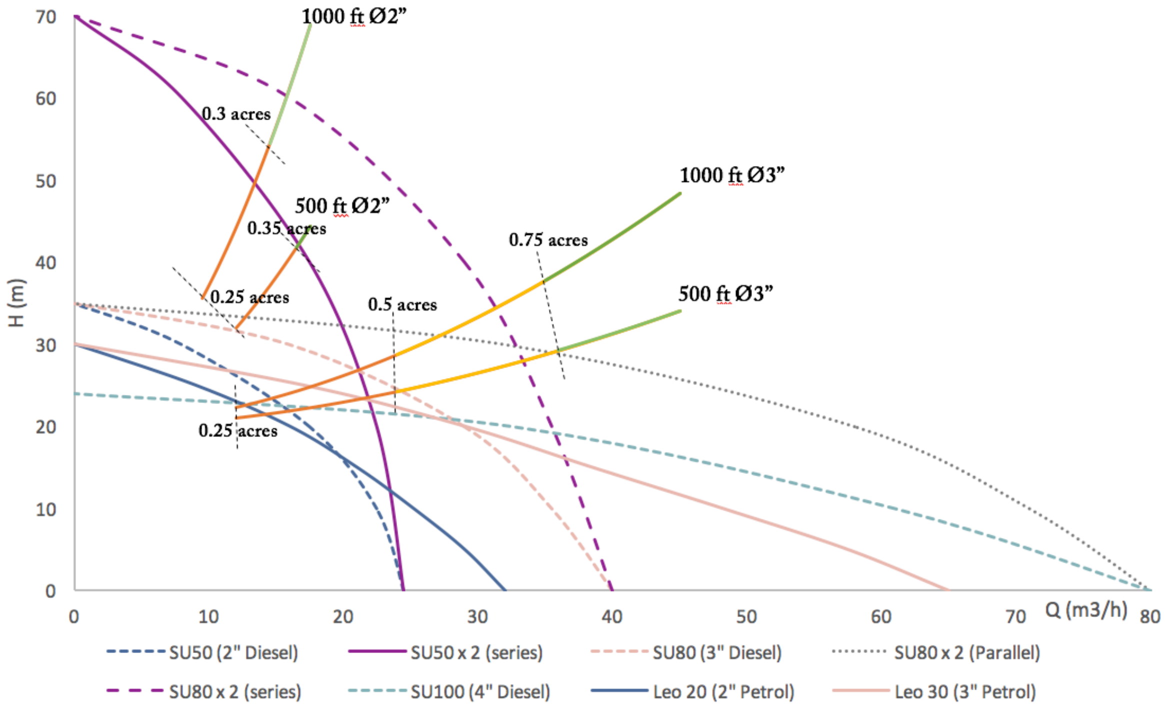


Figure 60: Pump curves for commonly used pumps in the project area and corresponding system curves for 2 different pipeline diameters and lengths.

The graph above shows that theoretically with the pumps commonly used and available, an existing 2" pipeline could usually be used to irrigate 0.25 acres (in one section) if 500ft long.

As most farmers seem to use the SU80 pump with a 12HP engine they could theoretically buy another SU80 for 45,000 MMK and run both in series with the same diesel engine, if the pipe is of class 8.5; as class 5 would 'burst'. On paper, one SU80 pump has a power requirement of 6.5HP so such a set up would not reach full power but would still provide notable head (pressure) gains. Using this approach an existing 2" pipeline could usually be used to irrigate over 0.3 acres (in one section) if 1,000ft long.

Farmers who have already set up 3" pipelines could irrigate over 0.5 acres in one section with pipeline lengths of up to 1,000ft. For 500ft it could just be possible with one SU80 pump and for 1000ft two pumps in series, as before, would be required.

For all these scenarios if the static head (elevation) is greater than 6m the situation would be different.

As drip irrigation plots tend to start small, with 0.25 acres being common, most famers within 500ft of the water source should be able to use their existing pumps. For farmers slightly further away, up to 1,000ft, a second pump body would need to be purchased for around 50,000 MMK ($40). For larger plots or longer pipelines, the system would need to be split into small enough sections to provide the required flow rate and pressure and pumped on a rotating basis. This would increase the overall pumping time but is a common practice in drip systems. Where the land is more inclined it would need to be assessed on a case by case basis.

While it is interesting to analyze what it theoretically possible some key questions arise; (1) does the theoretical situation fairly represent the realities, and (2) how can this actually be applied in the field? For the former the text box below suggests that there may be significant disconnect. For the latter, it is acknowledged that such analysis is not practical at the individual farmer level and is intended as a general guide for program planning and costing.

Theory ≠ Reality ?

Feedback provided by Asia Irrigation for two demo plots set up in February 2017 suggest that the above pump selection theory differs significantly from the field reality.

In February, Asia Irrigation set up additional drip irrigation demo plots in Southern Shan. They connected the system to farmers' existing 6 to 8 HP diesel engines with SU50 type (or similar) pumps. The plots were adjacent to the river and 1,200 feet away. According to the theoretical pump curves, the pumps should have been able to irrigate around somewhere between 0.15 and 0.2 acres. In reality, they could only supply a section of 0.03 acres (125m^2). This is a dramatic underperformance against the theoretical values.

The reason for large variance is unknown. It could be isolated incidents of worn out pump impellors and engines, or could represent a wider issue of pumps not being correctly geared and therefore run at sub-optimal RPM's, or something else. It is presumed that the issue is less likely to be the diesel engines as these tend to provide a theoretically greater horse power than the pumps actually require.

Saw Lu is not your average farmer. He is always thinking about how to improve and was inspired by his Mercy Corps study trip to Vietnam. With 26 acres, he has some resources which he can invest in new ideas and approaches. Before the MVMW program he didn't grow vegetables at all. Since realising the potential of off-season vegetable farming he has installed a deep tubewell which can irrigate 2 acres and dug a spring pond which can irrigate a further 2 acres. He is testing out the Yetagon drip system with bitter gourd, his favourite crop due to being less susceptible to disease. He thinks that other farmers in his village should start using sprinkler and drip systems in order to save water and grow more acres.

Financial Considerations and Viability

This chapter brings together the data and analysis from each of the preceding chapters in order to analyse the financial viability and profitability of increasing water access. We show that while rain water ponds are not economically feasible, shallow and even deep tubewells have significant potential to provide additional revenue with reasonable payback periods. Similarly, we explore the payback period for pump and pipe systems for pumping from existing streams. The benefits of increased water efficiency are briefly discussed and highlight the potential to more than double the effective 'value' of existing water.

Financial viability can be assessed by calculating the cost benefit ratio for an intervention based on the total design life period. Such a method would, for example, look at the cost of a pump spread over its expected lifespan and assess the additional likely income against this additional cost. However, from a farmer's perspective the concept of the payback period is more understandable and appropriate, as the costs will usually be upfront rather than spread over the life of the intervention. As such a payback period analysis, measured by crop cycles, is used when referring to interventions that have a payback period greater than one cycle. For more low cost interventions such as improved seeds or fertilisers, where the input is for one crop cycle only, a cost benefit ratio is more appropriate.

<table>
<tr><td colspan="5">Gross Revenue</td></tr>
<tr><td>Material Inputs</td><td>Fuel</td><td>Cost of Capital</td><td>Hired Labour</td><td>Family Labour</td></tr>
<tr><td colspan="4">Gross Margin</td><td>Net Margin</td></tr>
</table>

Figure 61: Components of farm expenditure and income. Modified from World bank Myanmar farm economics.

The MVMW baseline captures the details of farmers' total costs for the rainy and off season, split by input type as well as details of yield and selling price. These are detailed within the agriculture section of this report. Therefore, a profit per acre can be taken directly from the baseline. This was attempted but the range of data was considered too large. This is due to the large number of variables and variation within each cost and income category. In order to simplify the data and reduce the range of values, only the crop selling price is considered as a range of minimum, average and maximum. This was chosen as it is considered the most volatile variable and the most important factor in determining farmer decisions and behaviours. The other variables were considered on the basis of an average figure, determined following data cleaning.

Income per acre

Data from the MVMW baseline shows the large variation in the resulting income per acre across the range of farmers interviewed. The variation from the average is significant.

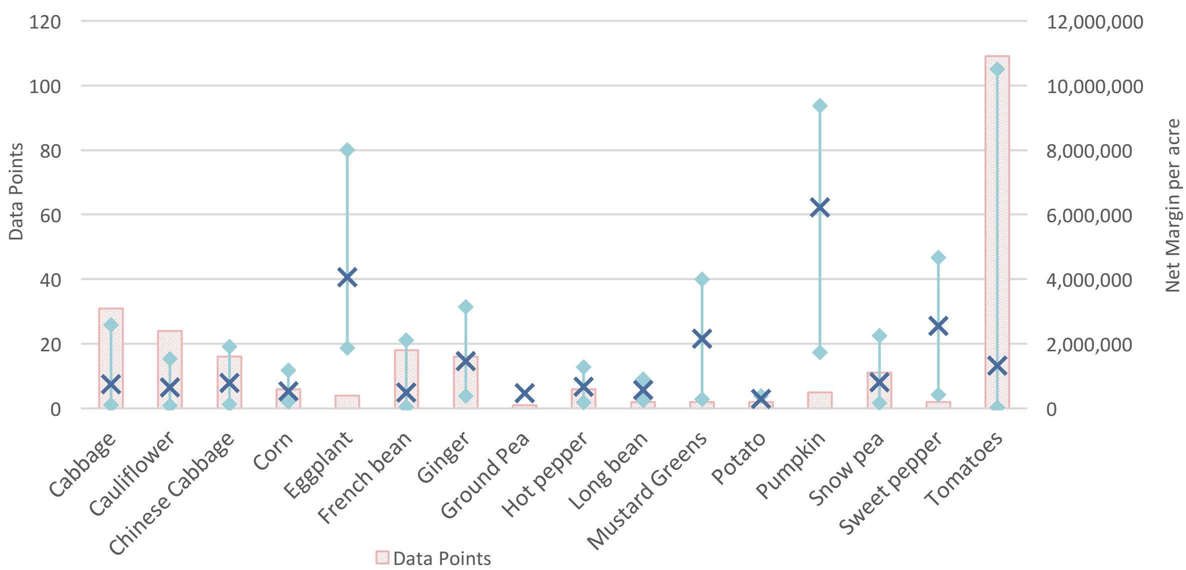


Figure 62: Net margin per acre during the rainy season (MVMW, 2016a)

Cost data from the agriculture chapter is compiled in the table below for selected vegetables.

Scenario		Tomato (Shan) Low yield	Tomato (Shan) Medium Yield	Cabbage	Cauliflower	Chinese Cabbage	Garlic (size C)
	Cost of inputs (excluding water)	570,000	570,000	520,000	390,000	770,000	850,000
	Yield in kg per acre (normal practises)	5,000	10,000	15,000	15,000	6,600	3,200
A	Selling price per kg (minimum)	122	122	28	33	42	579
B	Selling price per kg (1/2 market price average)	275	275	41	65	298	741
C	Selling price per kg (market price average)	550	550	81	129	596	1481
D	Selling price per kg (maximum)	976	976	203	244	915	2439
A	Gross revenue per acre	610,000	1,220,000	420,000	495,000	277,200	1,852,800
B	Gross revenue per acre	1,375,000	2,750,000	607,500	967,500	1,966,800	2,369,600
C	Gross revenue per acre	2,750,000	5,500,000	1,215,000	1,935,000	3,933,600	4,739,200
D	Gross revenue per acre	4,880,000	9,760,000	3,045,000	3,660,000	6,039,000	7,804,800
A	Net margin per acre	40,000	650,000	(100,000)	105,000	(492,800)	1,002,800
B	Net margin per acre	**805,000**	**2,180,000**	**87,500**	**577,500**	**1,196,800**	**1,519,600**
C	Net margin per acre	**2,180,000**	**4,930,000**	**695,000**	**1,545,000**	**3,163,600**	**3,889,200**
D	Net margin per acre	4,310,000	9,190,000	2,525,000	3,270,000	5,269,000	6,954,800
	Data Comparison						
	MVMW baseline off season (>= 0.5 acres) (sample size in brackets)	**737,000** (7)	-	**770,000** (4)	**1,061,000** (3)	**218,000** (2)	no data
	MVMW baseline rainy season (>= 0.5 acres) (sample size in brackets)	921,955 (93)	-	377,817 (21)	384,306 (6)	742,967 (5)	no data

Table 23: Net margin per acre for selected vegetable crops

Across the MVMW baseline data the average net margin per acre across all vegetables is 860,000 MMK ($688) in the rainy season and 1,109,000 MMK ($887) in the off-season. Excluding plots of less than 0.5 acres changes the net margins to 771,000 ($617) and 1,327,000 ($1,062) per acre respectively. As the cost of inputs are derived directly from the baseline (except garlic), the variation between the MVMW and scenario C (in Table 24) numbers is due to (i) yields often being lower than the figures derived above which are based on multiple sources, and (ii) selling prices often being lower in reality than what is being reported by the market price tracker. Farmers are commonly having either poor yields or poor selling prices.

Based on the above data a current net margin per acre figure of 800,000 MMK seems reasonable. As shown in the figures there is substantial potential to increase this through improved practises leading to increased yields or through being able to sell when prices are nearer the average or above. It could be assumed that a reasonable balance of these two factors would lead to net margins per acres of at least double; 1,600,00 to 2,500,000 MMK per acre for the purpose of the model.

Net margin figures for cost modelling

1: Current 'unimproved' practises, average net margin per acre = 800,000 MMK

2: 'Improved' practises (without drip irrigation), average net margin per acre = 1,600,000 MMK

Update: further net margin per acre information

Following the release of the final draft of this report further information was received from East West Seed. It was shared that, of the farmers that they have been working with in South Shan, the rough average net income per acre has been $675 (843,750 MMK) before the intervention and double at $1,350 (1,687,500 MMK) after the intervention. This closely matches the net margin figures predicted by this report for cost modelling and adds confidence to the payback period and benefit cost ratio figures.

Increasing water quantity (Cost Analysis)

This cost analysis is conducted from the perspective of a farmer who is unlikely to otherwise have money in a savings account. A present discounted value method is not used in this simplified method which looks at the benefit cost over a 20-year period. We do not consider the cost of credit.

The benefit cost ratio is considered to the farmer only. The initial capex and subsequent new recurring opex would also contribute significantly to the local economy and have further multiplier effects.

Item	Details	Cost (MMK)	Total Cost (MMK)	Data Source
Pond	100 x 100 x 6 ft 60,000 cu.ft = 1,699m^3 2" petrol pump with pipe	8,000,000 220,000	8,220,000 ($6,576)	DRD State
Deep Borehole / Tubewell	 150 feet deep 250 feet deep 350 feet deep Engine diesel 10HP & compressor pump & pipe	2,500 to 3,000 per feet 375,000 – 450,000 625,000 – 750,000 875,000 – 1,050,000 800,000	1,175,000 – 1,850,000 ($940 - $1,480)	Aung Ban Contractor 2 Pinlaung villages
Shallow Borehole / Tubewell	 30 feet deep 2" petrol pump with pipe	2,500 per feet 75,000 220,000	295,000 ($236)	Aung Ban Contractor

Rainwater Harvesting Pond

A typical pond, the type of which is common in the dry zone and delta areas, could store around 1700m^3 of water. If the water surface is fully exposed to the sun and wind it will evaporate at the ET_O rate of around 3.5mm per day. This equates to about 3.25m^3/day and 390m^3 over a 120-day crop cycle. Assuming some level of shade and wind protection we can assume a lesser total of around 225m^3 over a 120-day crop cycle. If not used for any other domestic or livestock purpose, around 1,475m^3 would remain for irrigation. Under furrow irrigation this could irrigate around 0.9 acres of vegetables and around 1.2 acres if used with sprinklers.

For furrow irrigation the payback period, without maintenance costs, would be around 24 crop cycles (years) based on the current typical net margins of 800,000 MMK per acre. With highly improved farming practises this could reduce to around 6 years. Regardless of the payback period, the high capital cost makes it unviable for farmers within the MVMW program.

per acre (MMK)	Current practises	Improved net margin per acre (1,600,000)	Improved net margin per acre (2,500,000)	*Comments*
Income				
Net Margin per season per acre	800,000	1,600,000	2,500,000	
Net Margin per season if pond irrigates 0.9 acres	720,000	1,440,000	2,250,000	*Assumes no sprinkler or drip systems*
Capex				
Pond	8,000,000	8,000,000	8,000,000	*DRD figure*
Petrol Pump and pipe	220,000	220,000	220,000	*Reasonable assumption*
0.25 acres land for pond	-	-	-	*Approx. 1000 m2*
Total Capex	*8,220,000*	*8,220,000*	*8,220,000*	
Opex / year				
Fuel costs per season	70,000	70,000	70,000	*Petrol pump*
Pond depreciation/ maintenance	50,000	50,000	50,000	*Estimate, no evidence*
Pump, compressor & pipe depreciation	44,000	44,000	44,000	
Pump, compressor & pipe maintenance (5%)	11,000	11,000	11,000	
Lost revenue from land in rainy season (0.25 acres)	200,000	400,000	625,000	*Based on the same net margin figures in the rainy season and 1 crop cycle. Assumes pond is on productive land.*
Lost revenue from land in off season (0.25 acres)	0	0	0	*Assumed that land could not otherwise be utilised in the off-season.*
Total Opex	*375,000*	*575,000*	*800,000*	
Total Net Margin per season with Opex	*345,000*	*865,000*	*1,450,000*	
Cost Benefit				
Payback Period	***24 seasons***	***10 seasons***	***6 seasons***	
20 year net margin income	*6,900,000*	*26,534,000*	*44,540,000*	
20 year Benefit Cost Ratio (simplified method) (rounded)	***0.8 to 1***	***3.2 to 1***	***5.4 to 1***	***No present discounted value method applied***

Shallow tubewells

During the field visits, shallow tubewells were found to irrigate between a quarter and one acre, due to relatively low water yields. In the villages which had known shallow groundwater, all farmers were able to afford drilling and pumping.

Due to the generally low water yields the below table analyses the cost benefit in the case of a quarter or half acre being able to be irrigated, irrespective of the irrigation method used.

per acre (MMK)	0.25 acres			0.5 acres		
	Current practises	Improved net margin per acre (1,600,000)	Improved net margin per acre (2,500,000)	Current practises	Improved net margin per acre (1,600,000)	Improved net margin per acre (2,500,000)
Net Margin per season per acre	800,000	1,600,000	2,500,000	800,000	1,600,000	2,500,000
Net Margin per season	200,000	400,000	625,000	400,000	800,000	1,250,000
Capex						
30 ft shallow borehole	75,000	75,000	75,000	75,000	75,000	75,000
Pump and Pipe	220,000	220,000	220,000	220,000	220,000	220,000
Total Capex	*295,000*	*295,000*	*295,000*	*295,000*	*295,000*	*295,000*
Opex / year						
Fuel costs per season	25,000	25,000	25,000	50,000	50,000	50,000
Borehole depreciation/ maintenance	0	0	0	0	0	0
Pump & pipe depreciation (5 year life)	44,000	44,000	44,000	44,000	44,000	44,000
Pump, compressor & pipe maintenance (5%)	11,000	11,000	11,000	11,000	11,000	11,000
Total Opex	*80,000*	*80,000*	*80,000*	*105,000*	*105,000*	*105,000*
Total Net Margin per season with Opex	*120,000*	*320,000*	*545,000*	*295,000*	*695,000*	*1,145,000*
Cost Benefit						
Payback Period	***2.5 seasons***	***0.9 seasons***	***0.5 seasons***	***1 season***	***0.4 seasons***	***0.3 seasons***
20 year net margin income	*2,400,000*	*6,400,000*	*10,900,000*	*5,900,000*	*13,900,000*	*22,900,000*
20 year Benefit Cost Ratio (simplified method) (rounded)	***8 to 1***	***22 to 1***	***37 to 1***	***20 to 1***	***47 to 1***	***78 to 1***

Deep tubewells

Analysing the cost benefit of deep tubewells is more complex due to the large number of variables that are involved including:

i. Required depth of the borehole and therefore the construction cost
ii. Yield of the borehole and therefore the area of land that can be irrigated
iii. Potential for the 1st borehole to fail and the cost that may be incurred, and further failures before success
iv. The irrigation method and therefore the area of land that can be irrigated
v. Length and size of pipe required to the field affecting the capex cost
vi. Distance and elevation of pumping to the field affecting the fuel consumption, pumping rate, pumping hours and fuel costs.
vii. Whether one or two crop cycles can be grown in the off-season. For this model, it is assumed that only one crop cycle is grown per season to be conservative.
viii. Yield and selling price of crop and therefore the net margin per season.

In order to fully consider all these variables a more detailed mathematical model is required. For this study, only three variables are considered:

i. The depth of the borehole, with models for 150, 250 and 350 feet shown in the graph that follows. As can be seen, although the initial capex varies significantly, the overall impact on the payback period and cost benefit ratio is not substantial.
ii. The acres which can be irrigated with the available water yield. This combines the yield of the borehole with the irrigation method utilised, although capex and opex for improved irrigation are not considered.
iii. The net margin per acre per crop cycle using three income points. This combines the yield, selling price and cost of inputs.

The table below shows the cost benefit analysis and payback period for a half and one acre irrigated under the three different net margin scenarios.

per acre (MMK)	1 acre			0.5 acre		
	Current practises	Improved net margin per acre (1,600,000)	Improved net margin per acre (2,500,000)	Current practises	Improved net margin per acre (1,600,000)	Improved net margin per acre (2,500,000)
Income						
Net Margin per season	800,000	1,600,000	2,500,000	400,000	800,000	1,250,000
Capex						
250 ft deep borehole	750,000	750,000	750,000	750,000	750,000	750,000
Pump, compressor & pipe	800,000	800,000	800,000	800,000	800,000	800,000
Total Capex	*1,550,000*	*1,550,000*	*1,550,000*	*1,550,000*	*1,550,000*	*1,550,000*
Opex / year						
Fuel costs per season	100,000	100,000	100,000	50,000	50,000	50,000
Borehole depreciation/ maintenance	0	0	0	0	0	0
Pump, compressor & pipe depreciation (6 year life)	133,300	133,300	133,300	133,300	133,300	133,300
Pump, compressor & pipe maintenance (5%)	40,000	40,000	40,000	40,000	40,000	40,000
Total Opex	*273,300*	*273,300*	*273,300*	*223,300*	*223,300*	*223,300*
Total Net Margin per season with Opex	*526,700*	*1,326,700*	*2,227,000*	*176,700*	*576,700*	*1,026,700*
Cost Benefit						
Payback Period	***2.9 seasons***	***1.2 seasons***	***0.7 seasons***	***8.8 seasons***	***2.7 seasons***	***1.5 seasons***
20 year net margin income	*10,534,000*	*26,534,000*	*44,540,000*	*3,534,000*	*11,534,000*	*20,534,000*
20 year Benefit Cost Ratio (simplified method)(rounded)	***7 to 1***	***17 to 1***	***29 to 1***	***2 to 1***	***7 to 1***	***13 to 1***

The graph below shows the variation of payback period relative to the acres which can be irrigated for two different net margin per acre scenarios.

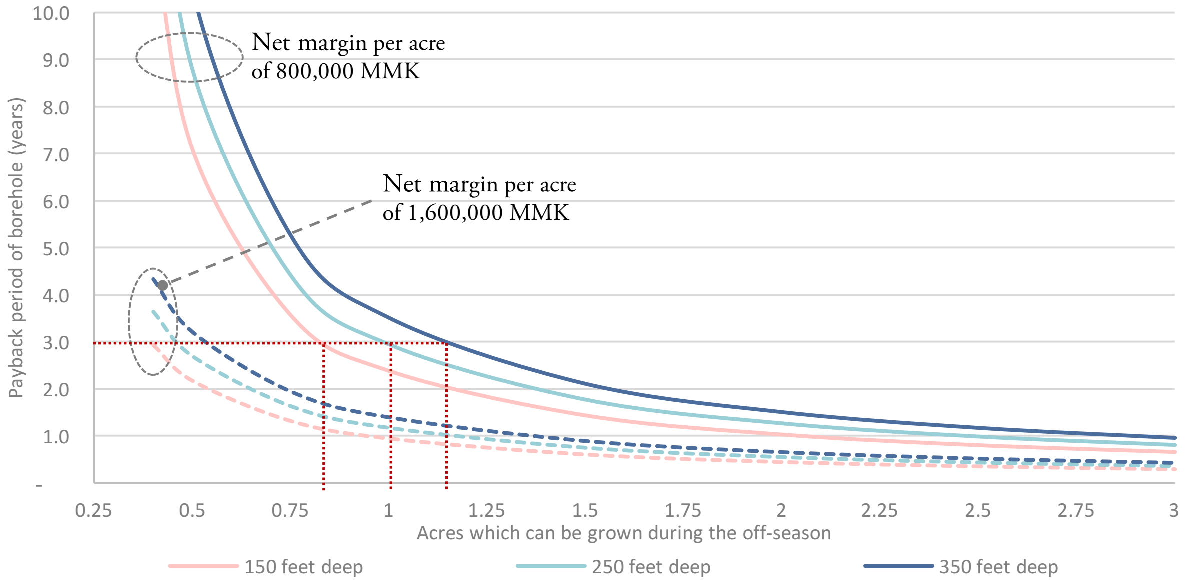


Figure 63: Payback period (of capex) for varying depths of borehole, acres that can be irrigated and the net margin per acre.

These payback periods do not consider the effect of the cost of credit or alternatively the potential interest that could be earnt, the time values of money. These can be considered by considering the net present value of the investment. This is shown in the figure below. The curvature of the line is due to the effect of the net present value. The point at which a line crosses the axis is effectively the true payback period.

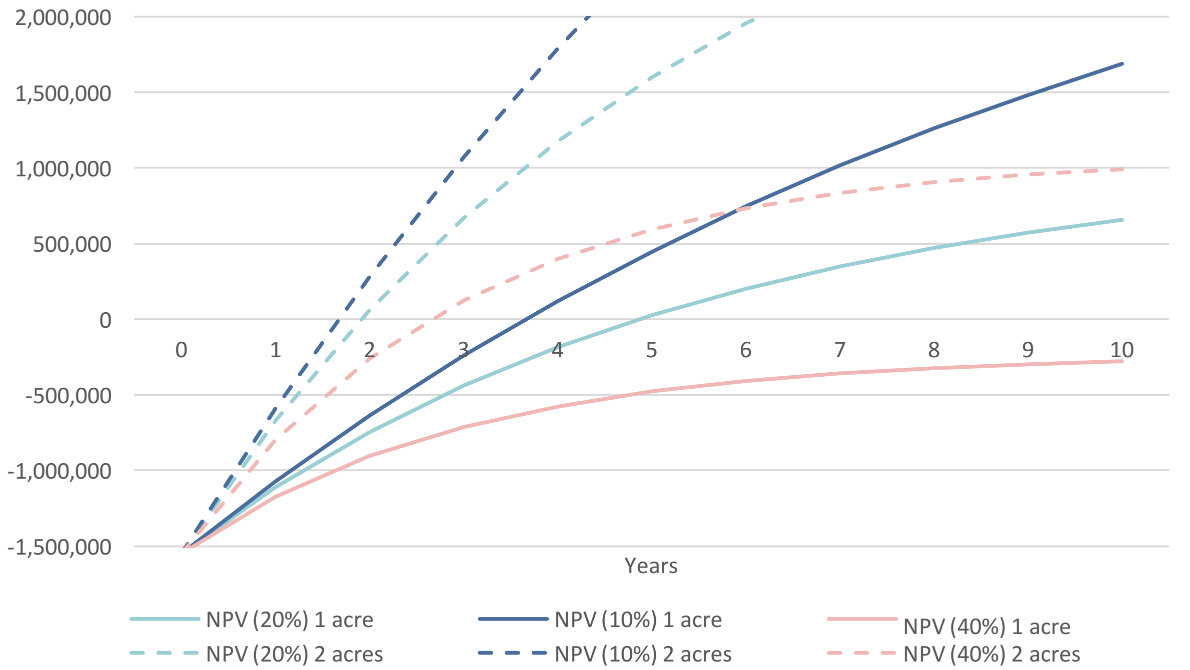
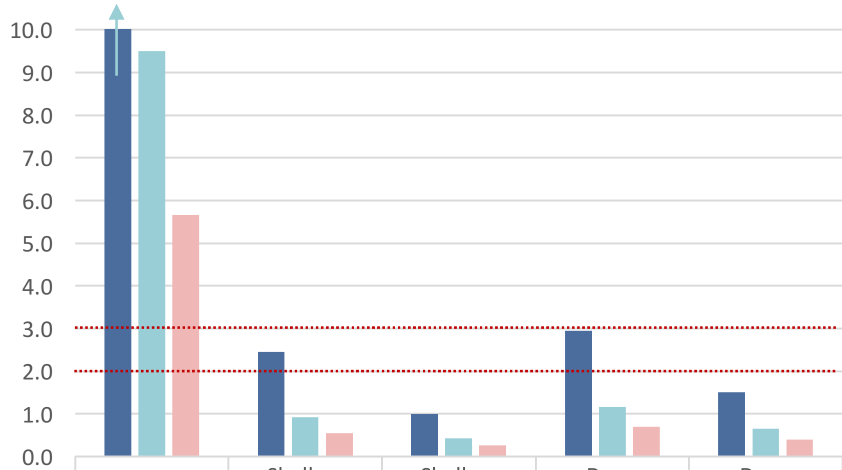


Figure 64: Net present value (MMK) of a deep tubewell investment of 1,550,000 MMK based on a resulting net income per acre of 526,700 MMK (as above). Solid lines represent if one acre can be cropped from the tubewell and dashed lines two acres.

Summary

Combining and comparing the payback period and 20-year benefit cost ratio is shown in the graphs and tables below. Payback periods greater than two or three years are not considered a reasonable investment given that credit for such investments would likely only be for one or possibly two seasons.

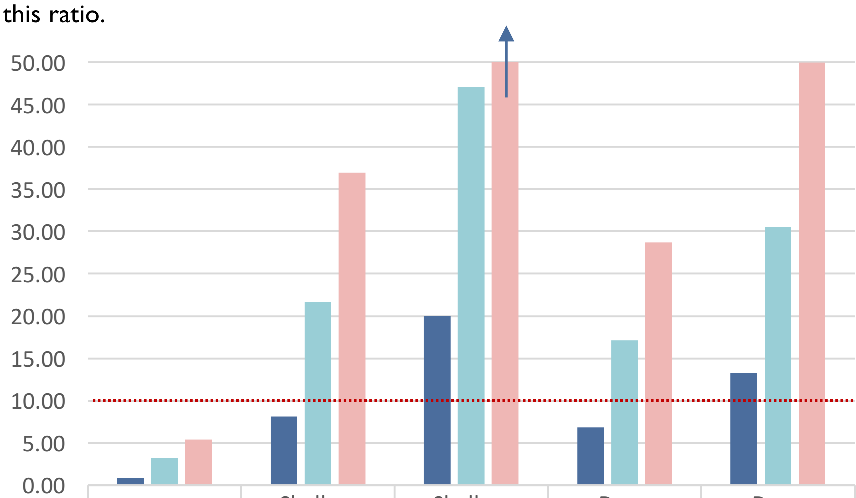


	Pond (100x100x6ft)	Shallow Tubewell 0.25 acres	Shallow Tubewell 0.5 acres	Deep Tubewell (250ft) 1 acre	Deep Tubewell (350ft) 2 acre
800,000 MMK per acre net margin	23.8	2.5	1.0	2.9	1.5
1,600,000 MMK per acre net margin	9.5	0.9	0.4	1.2	0.7
2,500,000 MMK per acre net margin	5.7	0.5	0.3	0.7	0.4

Figure 65: Payback period in off-season crop cycles (assumed one per year) for different water source development.

Even in the highest yield and therefore margin per acre scenario, rainwater harvesting ponds do not represent a good investment for the farmer. Shallow and deep tubewells, even with the lowest net margin scenario, do represent a sound investment for the farmer.

A 20-year benefit cost ratio of greater than ten to one is considered as the target minimum. Shallow and deep tubewells that are only able to irrigate lesser acres would require some improvement in the yield and/or selling price in order to achieve this ratio.



	Pond (100x100x6ft)	Shallow Tubewell 0.25 acres	Shallow Tubewell 0.5 acres	Deep Tubewell (250ft) 1 acre	Deep Tubewell (350ft) 2 acre
800,000 MMK per acre net margin	0.84	8.1	20.0	6.8	13.3
1,600,000 MMK per acre net margin	3.23	21.7	47.1	17.1	30.6
2,500,000 MMK per acre net margin	5.42	36.9	77.6	28.7	50.0

Figure 66: 20-year cost benefit ratio, from the farmer's perspective, for different water source development.

Increasing existing water utilisation with pump and pipe

For farmers who have land within a reasonable distance of an existing water source (usually up to 3,000 ft) but have not purchased a pump and pipeline, the benefit cost and payback is investigated. The table below explores two pipeline lengths, 500ft and 2,500ft. As with previous analysis three net margin per acre income figures are modelled.

Per acres (MMK)	500 ft pipeline			2500 ft pipeline		
	Current practises	Improved net margin per acre (1,600,000)	Improved net margin per acre (2,500,000)	Current practises	Improved net margin per acre (1,600,000)	Improved net margin per acre (2,500,000)
Income						
Net Margin per season	800,000	1,600,000	2,500,000	800,000	1,600,000	2,500,000
Capex						
Diesel engine & pump (assume 470,000 up to 1500 ft and 570,000 for pipeline > 1500 ft)	470,000	470,000	470,000	570,000	570,000	570,000
Pipeline (assume 2" dia up to 1,500 ft length & 3" dia for pipelines > 1,500 ft)	105,500	105,500	105,500	798,750	798,750	798,750
Other costs buffer (15%)	86,325	86,325	86,325	205,313	205,313	205,313
Total Capex	*661,825*	*661,825*	*661,825*	*1,574,063*	*1,574,063*	*1,574,063*
Opex / year						
Fuel costs per season	100,000	100,000	100,000	100,000	100,000	100,000
Pipeline depreciation (20 year life)	5,275	5,275	5,275	39,938	39,938	39,938
Engine and pump depreciation (6 year life)	78,333	78,333	78,333	*95,000*	*95,000*	*95,000*
Engine and pump maintenance (5%)	23,500	23,500	23,500	*28,500*	*28,500*	*28,500*
Total Opex	*207,108*	*207,108*	*207,108*	*263,438*	*263,438*	*263,438*
Total Net Margin per season with Opex	*592,892*	*1,392,892*	*2,292,892*	*536,563*	*1,336,563*	*2,236,563*
Cost Benefit						
Payback Period	***1.1 seasons***	***0.5 seasons***	***0.3 seasons***	***2.9 seasons***	***1.2 seasons***	***0.7 seasons***
20 year net margin income	*11,857,833*	*27,857,833*	*45,857,833*	*10,731,250*	*26,731,250*	*44,731,250*
20 year Benefit Cost Ratio (simplified method)(rounded)	***18 to 1***	***42 to 1***	***69 to 1***	***7 to 1***	***17 to 1***	***28 to 1***

Table 24: Benefit cost and payback period for pump and pipe for a 1 acre plot

The payback period and benefit cost ratio is dependent on the size of the plot which is to be irrigated. The graph below looks at the relationship between the three variables of net margin per acre income, length of the pipeline and the acres which are to be irrigated. During the field visit most farmers who had not yet set up pumping systems had smaller plots and/or were further away from the water source. In the case of a farmer with a half-acre plot 1,500 feet away from the water source, the payback period would be over 3.5 crop cycles based on the 800,000 MMK net margin per acre.

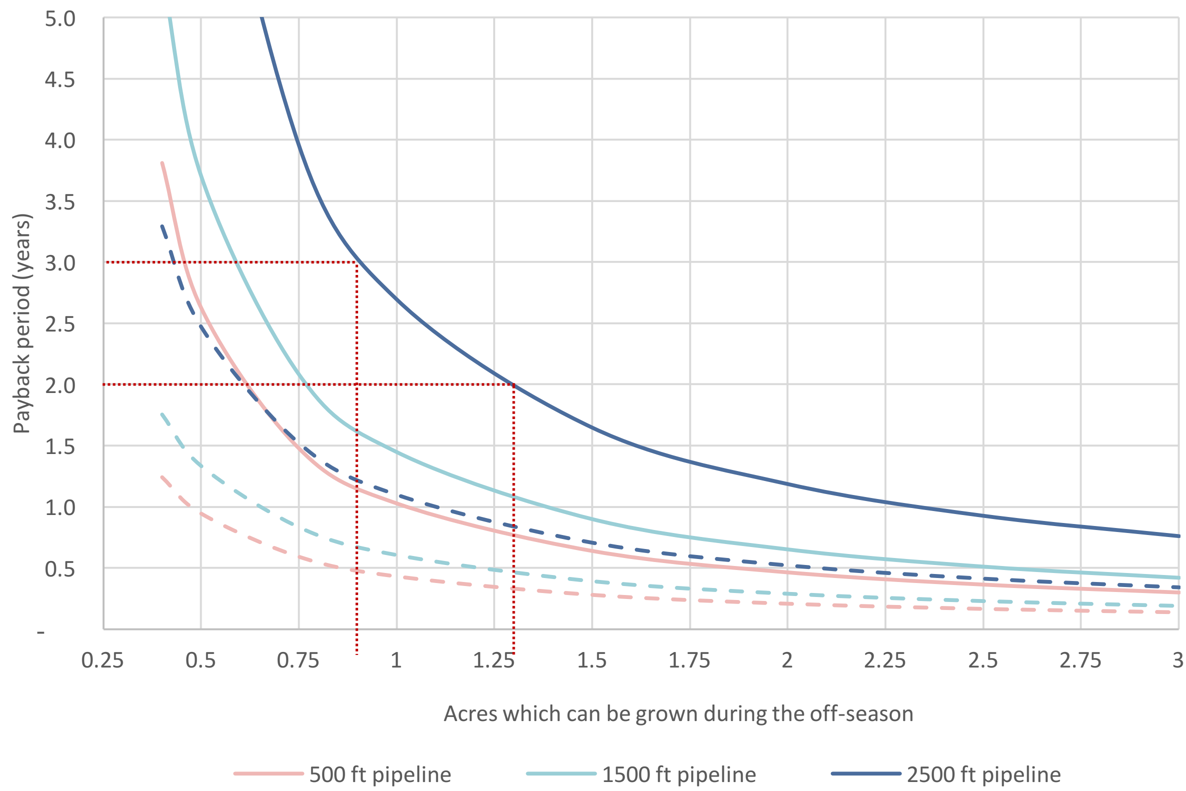


Figure 67: Payback period for diesel engine pump and pipe setup dependant on the length of pipeline and acres which can be irrigated. The dotted lines represent 1,600,000 MMK net margin per acre. The solid line represents 800,000 MMK net margin per acre.

Increasing water efficiency

Analysis of different irrigation technologies and efficiencies is beyond the scope of this report. However, water savings through increased irrigation efficiency would theoretically free up more water which could be used to crop additional acres. The extent to which this applies depends upon how much of the current irrigation water already flows back into the water source, where it can be re-used downstream. As such sometimes the water savings from increased irrigation efficiency are less than would be expected when looking at the macro basin level.

Various figures for the application efficiency of different irrigation systems exist in the literature as they depend on specific local conditions. In particular, the efficiency of furrow irrigation can vary dramatically depending on the soil type, infiltration rates, climate and design of furrows.

Irrigation System	Application Efficiency (Ea)
Furrow	30 % - 70 %
Overhead	60 – 80 %
Drip	80 – 95 %

Table 25: Possible irrigation method application efficiencies

The total crop irrigation water requirement is directly related to the application efficiency.

Irrigation requirement (IR) = Crop water requirement (ET_c) / Application efficiency (Ea)

As calculated in the prior crop water requirement section, based on a 1st December planting date and the climatic conditions in Taunggyi, both cabbage and tomato have a total crop water requirement per cycle of around 1,700m^3 per acre. The graph below highlights simply the impact of the irrigation application efficiency on the total crop irrigation requirement.

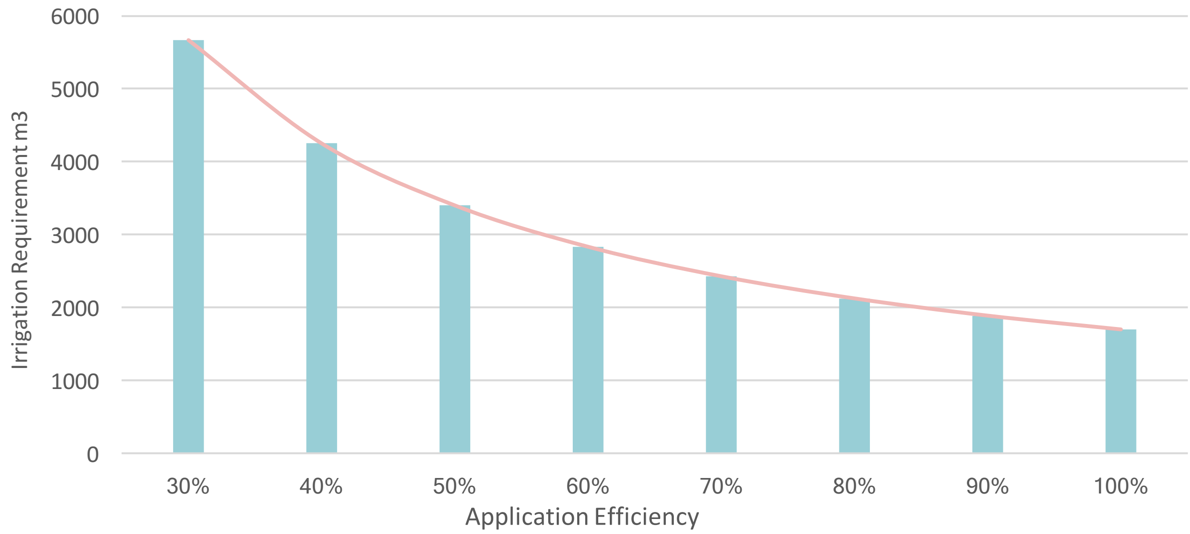


Figure 68: Total irrigation requirement per acre for tomato and cabbage with varying irrigation application efficiencies

To highlight a previous point, if tomato is grown with 40% efficient furrow as compared to a 70% efficient sprinkler system, at the micro-level it suggests a relative water 'loss' of 1,821m^3. However, if 60% of the water not used by the plant flows back into the water supply for other farmers to use, the actual water 'loss' would be a much lesser 728m^3. A further study would be needed to estimate the actual water 'savings' within the South Shan context.

	Tomato	Cabbage	Garlic
Crop water requirement (m3)	1,683	1,691	955
Current situation			
Irrigation requirement with <u>50%</u> application efficiency	3366	3382	1910
Current yield kg/acre (table 24)	5000	15000	3200
Selling price scenario (table 24)	B	C	B
Net margin per acre (table 24)	805000	695000	1,519,600
Net margin per m3	***239***	***205***	***796***
With improved irrigation			
Irrigation requirement with <u>75%</u> application efficiency	2244	2255	1273
Yield with 20% increase from improved irrigation in kg/acre (table 24)	6000	18000	3840
Selling price scenario (table 24)	B	C	B
Net margin per acre (table 24)	1080000	938000	1,995,440
Net margin per m3	***481***	***416***	***1567***
Net margin per m3 increase	***101%***	***102%***	***97%***

Table 26: Net margin per m3 of water with and without improved irrigation

The table above demonstrates the possible change in the net margin per m^3 of water with current and improved irrigation practises. Several assumptions have been made and therefore these figures aim only to show the general trend. For this example it is assumed that the yield increased by 20% through improved irrigation, but that the production costs stay the same. In reality it is likely that the labour costs would reduce.

Indicatively, the table highlights that a doubling in the 'net margin income' per m^3 of water can be achieved by a modest increase in irrigation efficiency and yield. Scaling this theory up across the project area it could be suggested that it is possible to double the effective value of the currently available water.

Labour savings from sprinkler usage for Garlic in Pinlaung

Naung Lin is a village in Pinlaung which primarily grows garlic in the off-season and which has a high uptake of sprinkler systems. A farmer explains that previously he used to have to hire five people for a full day every seven days for his one acre plot of garlic. This used to cost 20,000 MMK per week. Now, with the sprinkler system, he uses twelve litres of diesel at a cost of 9,000 MMK and one person for six hours, a total combined cost of 13,000 MMK. Over a five month crop cycle, representing 21 weeks, the farmer will save 147,000 MMK ($118). With an initial cost of around 800,000MMK ($640) it will take around six crop cycles to achieve pay back.

Yield benefits of improved drip irrigation

Analysing the yields and cost benefit of different irrigation methods was beyond the scope of this study and insufficient data was available from the field visits. However, some guideline data has been provided by Asia Irrigation based on their learnings and experience within Cambodia.

tonne / ha drip irrigation systems	Average Yield using normal inputs	Possible yields using improved seeds, fertigation, etc.	% increase (midpoint to midpoint)
Tomato	30 - 40	50 – 80	***86 %***
Chili Pepper	20 – 25	20 – 35	***22 %***
Egg Plant	25	35	***40 %***
Cucumber	30	50 – 100	***67 – 233 %***
Bitter Gourd	14 – 18	40	***150 %***
Long Beans	20	20 – 25	***13%***

Table 27: Yield increases from drip fertigation in Cambodia

Drip and Fertigation Cost Benefit in Cambodia

Previously a farmer in Cambodia was growing cucumber with a yield of 30 tonnes/ha resulting in a profit of $661 for a 1000m^2 plot. After support from Asia Irrigation, which included fertigation and the addition of calcium and magnesium sulphate to the normal urea MPA and KCI, the yield rose to 50 tonnes/ha, a 67% increase. The cost of fertilizer increased by $128 from $89 to $217, but the profit rose by 56% to $1,033. This represents a benefit cost ratio of 2.9 to 1 on the increased cost of fertilizer.

Enabling Environment

Water Management

Of the twelve villages visited, ten had access to varying levels of off-season irrigation water. Of these, all displayed evidence of a high level of needs based self-organisation and capable water resource management. None of the communities had any form or formal water user association or management group, instead resolving issues as they arise. The approaches used appear to vary from village to village based on existing community dynamics and social structures. A common theme was the role of the village leader in helping to resolve any conflicts that cannot be mutually resolved, although such cases were reported as rare.

In the dry zone of Myanmar conflict over rice irrigation canal scheduling can often lead to reports of inter-farmer conflict. During the field visits we heard of no instances of serious conflict, either current or past. The variation could be due to the different way in which the respective irrigation resources are viewed. In the dry-zone irrigation canals are an institutional shared resource which requires a level of management to schedule the irrigation of different parcels of land. Conversely while the natural streams in South Shan are also communal by nature, their usage is individualized. Villages visited which were downstream did not report negotiating with upstream villages. There seems to be a common understanding that (i) it is fair for farmers nearest the natural water to have first priority over its use, and (ii) it is fair for farmers upstream to have first priority over farmers downstream. This is not an equitable approach, but it appears to be a consensus that has formed a natural equilibrium of usage.

Naung Lin village in Pinlaung township has a natural spring. Over the past 3 years they have increased their irrigated area from 20 to 50 acres as more farmers saw the cost-benefit. Last year, they collectively decided to not irrigate any further land after witnessing the water levels reduce, particularly towards the end of the season. By contrast Inn Gaung village, which is downstream had to reduce their irrigated area for the second crop (February to May). Previously around 60 acres could be irrigated throughout the off-season, but now this has reduced to 20 acres nearest the stream. There has been no discussion or negotiation regarding the water resource with the upstream villages.

Water User Associations

The promotion of water user associations (WUA's) as a tool for increased local governance has been a central component of global water reform programs. Often within the context of irrigation WUA's are established to transfer water management from government to communities, usually in relation to government constructed irrigation canals. However, experiences both from Asia and globally have highlighted that often the majority of WUA's do not actually function, existing only on paper (Ghazouani et al., 2012; Mukherji et al., 2009). They can also be expensive to establish and maintain due to the level of field support required.

On the basis of the irrigated communities visited and feedback from the field staff, there appears to be no evidence of a problem that a water management program would solve.

Pump sharing and ownership

In the dry-zone of Myanmar it has been reported that informal water trading and inter-farmer hiring of pumps appears to be commonly practised, along with some cases of cost sharing and mutual collectives (Senaratna Sellamuttu et al., 2013). In 2010 it was reported that 3,765 households in South Shan owned water pumps and 3,031 borrowed them from another farmer (MOAI, 2013a). By contrast, field visit observations and feedback from the Mercy Corps field team did not find any instance of pump sharing, inter-farmer rental or informal water trading. Each farmer was found to be responsible for purchasing and maintaining their own pump system. In Nang Ong Ywar Ma village in Kalaw this was particularly evident, with 40 sets of diesel engines and pumps lined up along a short stretch of the river. The reasons for this individual approach were not part of the FGD questions. Of the few farmers this was discussed with, all referred to concerns with the higher possibility of breakdowns and increased maintenance costs.

Access to Credit

Based on farmer, supplier and team consultations there are no credit streams openly available to farmers for purchasing mechanised pumping equipment, pipes, PVC sprinkler components or modern drip irrigation.

Of the four pump suppliers visited, all considered that there would be notably more demand if there was a credit system available for irrigation equipment, particularly for engine and pumps setups. However, farmers consistently reported the need for affordable flexible credit of at least one, but ideally two, full seasons. The need for some form of loan insurance, waiver or extension provision was also considered essential due to the risk of either losing a full crop or unviability of the selling price.

Product specific credit

Farmers reported that Prime offer one season of credit for full drip irrigation systems to their potato contract farmers. Both villages in Pindaya that have Prime contract farmers reported borrowing around 2 million MMK ($1,600) for the systems.

Yetagon, the outward brand of Proximity Designs irrigation products, offers credit for Yetagon products. They also offer credit of up to 350,000 MMK for any farming inputs. Both products have an interest rate of 5% per month. Of the farmers met in the ten irrigated villages visited none were aware of these credit options and the one farmer who had purchased their drip system had done so with cash.

Other credit

Most notable is the LIFT supported Yoma Bank Agribusiness Finance Program (AFP), which is specifically intended for the hire purchase of farm machinery such as tractors and threshers. The partnership is helping to develop "a more robust, inclusive rural financial market and contribute to the economic development of the rural sector by improving farm productivity and stimulating the growth in off-farm businesses" (Yoma, 2017). The AFP allows for hire purchase agreement terms to be reduced from a 30% to as low as 10% deposit and increases repayment periods from one to up to three years. Based on information from a supplier visited the AFP does not consider irrigation equipment as part of the program. The program is due to run until the end of 2018 (LIFT, 2017).

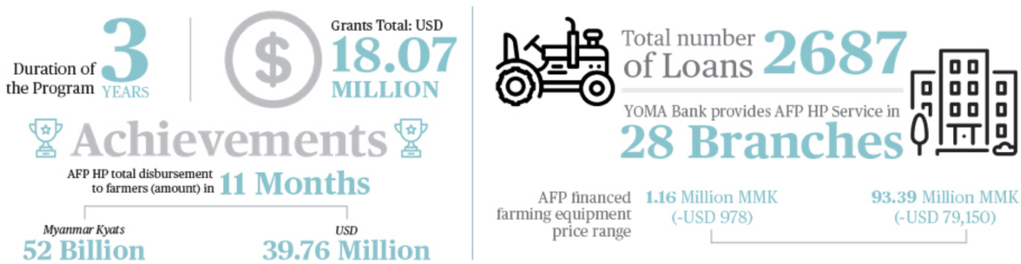


Figure 69: LIFT support Yoma bank AFP graphic (Yoma, 2017)

Myanmar Agricultural Development Bank (MADB) offers credit of only 100,000 MMK ($80) per acre for rice or sugar and only 20,000 MMK ($16) per acre for other crops, up to ten acres. As such, it makes no notable contribution to facilitating irrigation investments (FAO IC, 2014).

A LIFT commissioned report did not identify any microfinance loan providers that can provide the amount needed to make irrigation investments (FAO IC, 2014).

Institutional and Policy Environment

There do not appear to be any policies which would restrict or discourage the off-season irrigation of vegetables. There are currently no known policies or regulations regarding the individual or group extraction of water from springs and streams for irrigation purposes.

The Department of Irrigation (DoI) is responsible for dam and river diversion projects whereas the Water Resource Utilisation Department (WRUD) is responsible for government support of river or groundwater pumping. The WRUD also owns drilling rigs and installs irrigation boreholes in areas that are considered economically worthwhile. The groundwater flow division of the WRUD is responsible for collecting and organising hydrogeological data. Crop information is collected by the Land Use Department. All departments are under the Ministry of Agriculture, Livestock and Irrigation.

While the topography of South Shan is particularly conducive to new small scale weir and dam projects, the DoI is not currently pursuing new constructions, instead focusing on renovating and upgrading existing farmer or DoI constructed dams. They acknowledge that the Ministry may change this approach, but plans are currently unknown. The DoI State Director reported that getting farmer consensus for the location of new dams and extent of flooded area is increasingly difficult.

Potential areas where policy creation, reform or improved governance could benefit off-season vegetable growing include:

i. Policy which encourages and enables the adoption of improved water technologies such as sprinkler and drip usage.
ii. A financial environment where farmers can access credit to expand or improve their off-season irrigation, such as through purchasing pumps, pipes or sprinkler and drip sets. This could potentially be through an expansion of the current LIFT supported Yoma bank AFP program.
iii. Well considered incentives or subsidies to encourage the uptake of sprinkler and drip systems. It is interesting to note that between 1997 and 2013 in the USA around one billion dollars was provided in subsidies through the 'Environmental Quality Incentives Program' to increase the efficiency of irrigation water use (Nixon, 2013). Drip irrigation equipment subsidies are currently provided by the Government of India, the central government subsidises 35% and the State tops this up to either 50% or 100% for the poorest farmers.
iv. An improved risk mitigation environment that gives farmers more confidence to invest in irrigation improvements. This could be in the form of:
    a. Increased prevalence of contract farming.
    b. A national crop insurance scheme such as India's new "Pradhan Mantri Fasal Bima Yojana".
    c. Improved awareness of likely selling prices; possibly through statistical analysis of national market trends in production.
v. Policy or procedures that focus on the individualisation of irrigation and how to deal with ensuring equitability, conflict mitigation and environmental sustainability.

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Annex A: Remote Sensing GIS Analysis Methodology and Results

Authored by Dr Sajid Pareeth

Objective

To estimate dry season irrigated area and the area of water sources in five townships of South Shan state in Myanmar during the season from December 2015 to April 2016 using Satellite data.

Data

All the Landsat data available from three scenes covering the five townships and larger area covering major part of South Shan district is downloaded and processed.

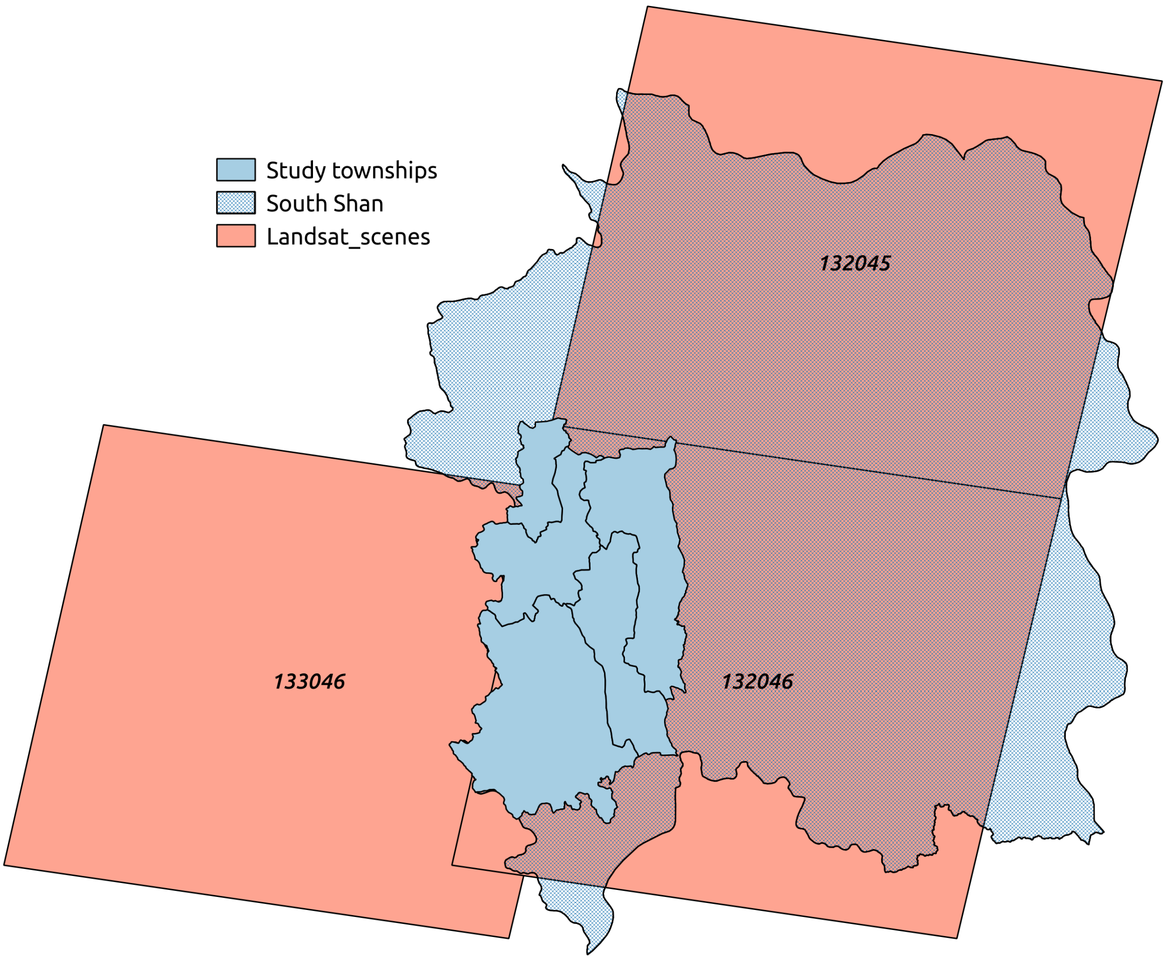


Figure: Study area and the Landsat 8 Satellite scenes used for this study.

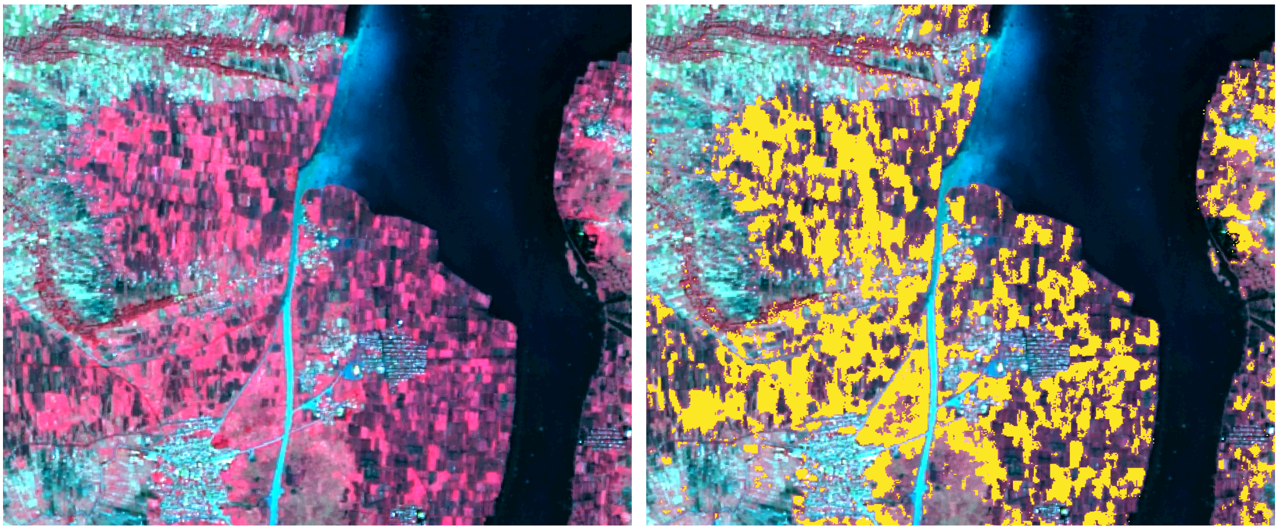
For each scene, data from multiple dates were downloaded and processed (see Table 1). Each Landsat tile covers 232 x 232 km area approximately. All the Landsat data were processed at a spatial resolution (pixel size) of 15m.

Scene 132045	Scene 132046	Scene 133046
27-12-2015	27-12-2015	18-12-2015
13-02-2016	13-02-2016	19-01-2016
17-04-2016	17-04-2016	08-04-2016

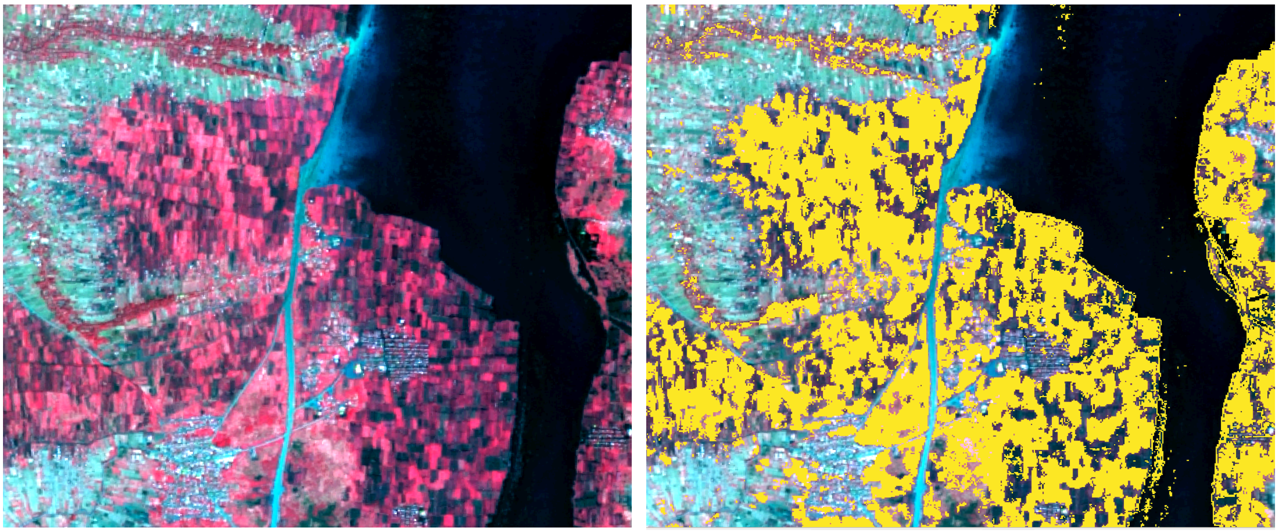
Table: Dates of acquisition per scene, used in this study

Dates of Acquisition of 132045 and 132046 are same, as both scenes fall in the same orbit of the satellite. For the scene 133046 the dates used are different, though close enough to combine monthly. There were data from other dates too, but due to cloud coverage only those listed in Table 1 were usable. Hence the final estimated crop area are monthly, representing the months of December 2015, February 2016 and April 2016. While the estimated area of water sources are combined for the entire dry season cover December 2015 to April 2016.

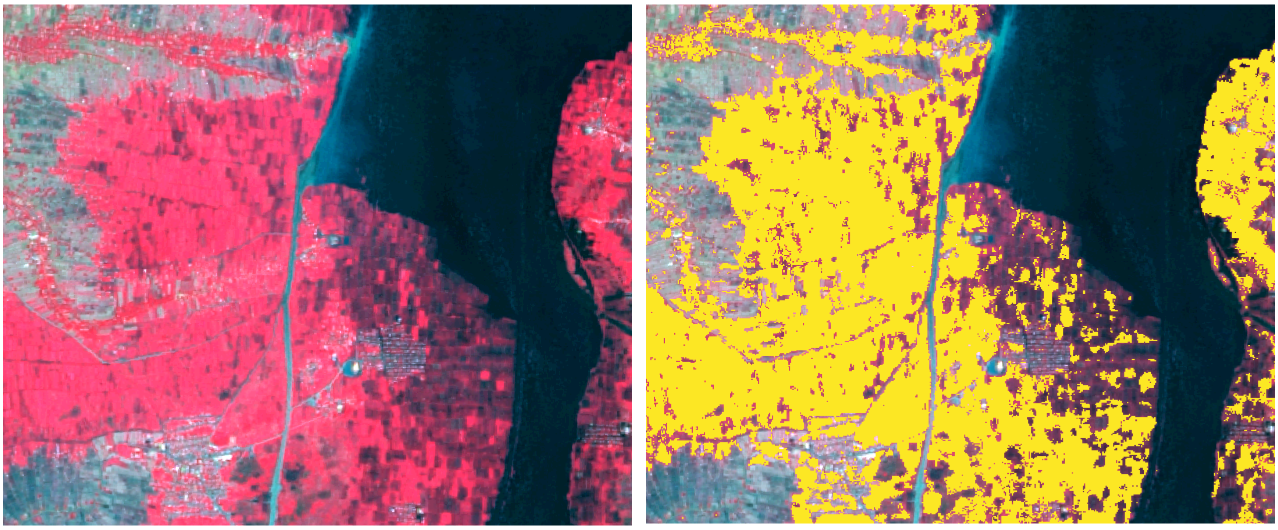
Definition of irrigated area: The irrigated area here represents the area with grown stage of crops which can be distinguished in a satellite image due to its high chlorophyll content. So for each month, those pixels were extracted using Machine learning algorithm - Random Forest. An exclusive training sites were developed from multiple images, by drawing manually some of the irrigated area locations. These training sites were used for developing the Random Forest Model.



27-12-2015



13-02-2016



17-04-2016

Figure: The above images show an area in the township Nyaungshwe and covered by Landsat scene 132046. On the left side the False color composite of each date images are given. The bright red color (due to high chlorophyll content of grown crops, actual green but red here due to false color composite) pixels represents crops at grown stage. Blue pixels represent a lake. On the right hand side the yellow pixels are those selected as irrigated area using Random Forest Algorithm.

Results

Two sets of data are delivered, 1) Results confined to study townships, 2) Results covering larger area covering all three Landsat scenes with major part of South Shan. Moreover, a table with statistics based on five townships are given below.

For each set following data are delivered:

i. LC8_crop_studyarea_Dec2015.tif – Irrigated area in December 2015, estimated from December images
ii. LC8_crop_studyarea_Feb2016.tif – Irrigated area in February 2016, estimated from February images
iii. LC8_crop_studyarea_Apr2016.tif - Irrigated area in April 2016, estimated from April images
iv. LC8_crop_dryseason_studyarea_2015_2016.tif – Combined Irrigated area for entire Dry season, estimated from above three results.
v. LC8_water_dryseason_studyarea_2015_2016.tif – Combined water sources area from the entire dry season

The same set for larger area of South Shan is also provided as second set (Huge data due to large area).

All the results are in Geotiff format with 15 m spatial resolution (pixel size). It can be opened in any GIS software like Quantum GIS (QGIS). If using QGIS, it would be good to use the openlayers plugin which enable Google satellite data as base map for comparison purposes.

All files are in the UTM 47 North (EPSG:32647) Coordinate system.

Irrigated Area (Acres)	Pinlaung	Kalaw	Taunggyi	Pindaya	Nyaungshwe	**Total**
December 2015	3,186	3,526	10.295	2,309	16,207	**29,689**
February 2016	3,102	1,206	13,035	366	21,603	**37,740**
April 2016	4,831	3,813	3,708	445	24,470	**33,009**
Cropped area (Off-Season)	10,174	7,747	19,935	2,978	37,772	**67,881**
Water surface area (Off-Season)	5,205	1,163	658	135	19,873	**25,736**

Table: Area statistics of irrigated area and water sources area in acres over five townships of South Shan district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Associates